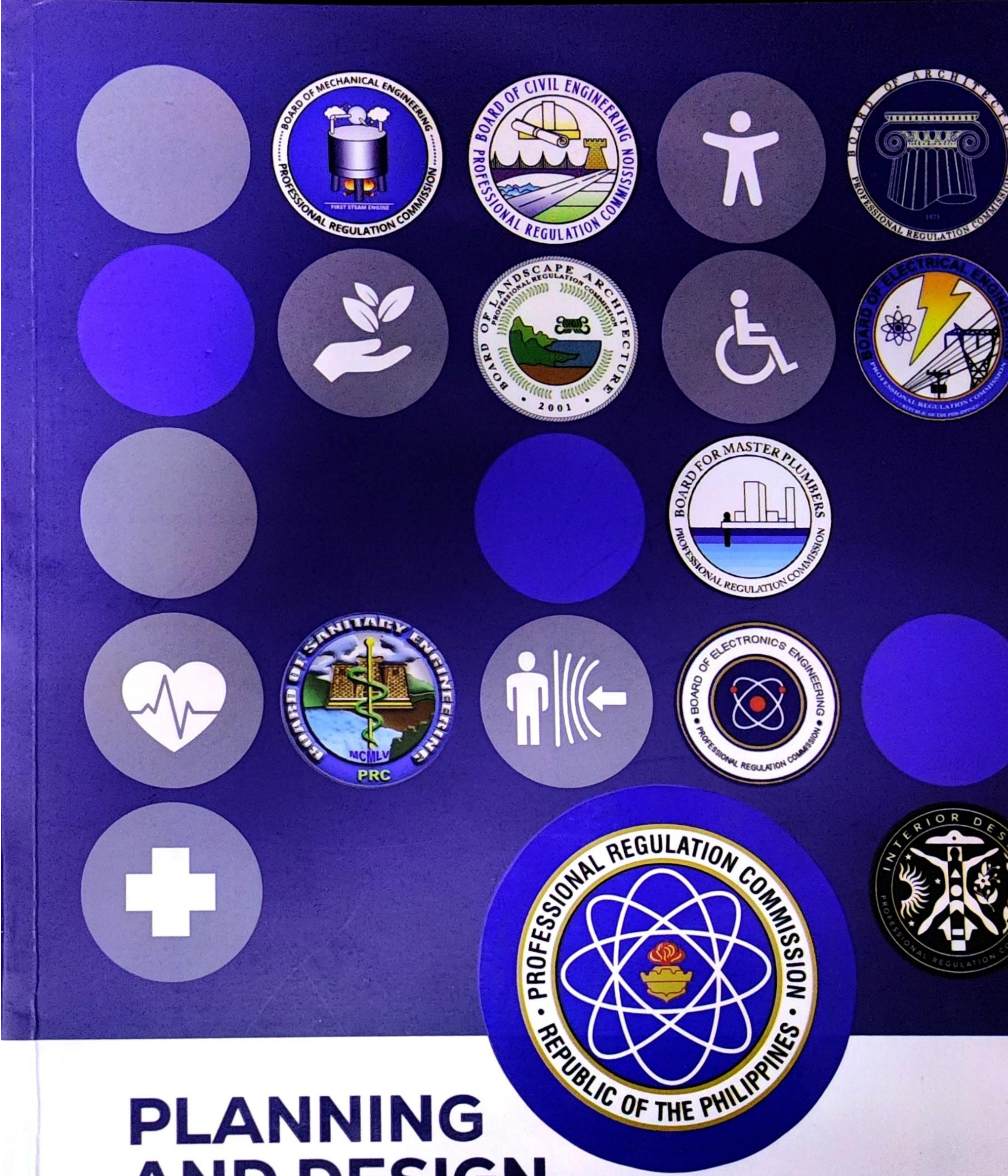
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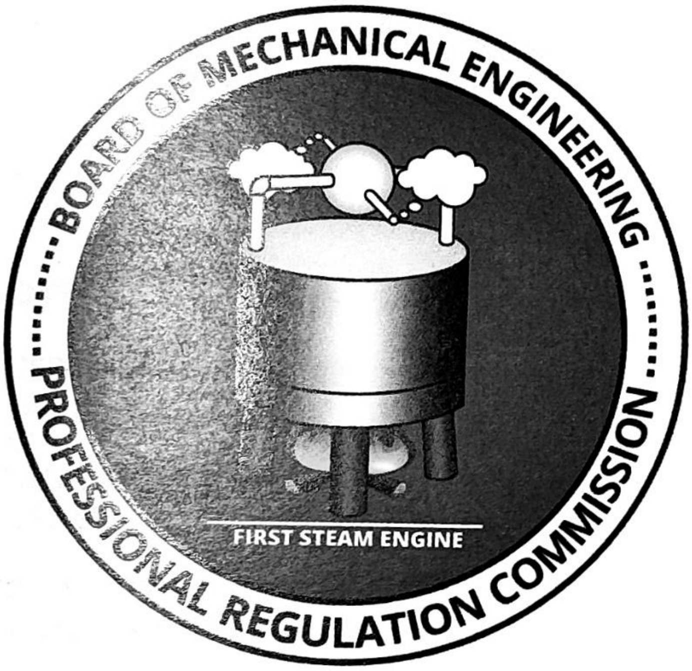
PLANNING AND DESIGN GUIDELINES

FOR HOSPITAL FACILITIES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FOREWORD

The pandemic 2020 has brought to light the limitations of many of our hospitals and healthcare facilities to manage the severity of the epidemic. The occurrence of widespread airborne infection has given rise to discussions on the preparedness of our healthcare facilities for similar adversities. Therefore, this design manual aims to provide the fundamental and critical aspects of designing the mechanical systems that are essential to hospitals and other healthcare facilities.

In this manual, the mechanical systems described herein are the HVAC, Fire Protection, Lifts and Conveyances, Medical Gases, Water and Wastewater Mechanical Systems, and Emergency Power Generation Systems. These mechanical systems are major mechanical systems that are necessary to provide the operative indoor environment for wellness, promote and advance treatment, and support the effective discharge of medical services.

The strategic objectives of this manual are to provide the parameters, approaches and suggested methodologies in the design of systems that will control airborne infection in hospitals and healthcare facilities, minimize risks of nosocomial or hospital-acquired illnesses, and minimize risks of both natural and man-made disasters. The manual also espouses the appropriate operation and maintenance of systems to avoid unnecessary interruptions to discharge critical medical procedures requiring mechanical systems.

However, this edition of the manual does not include provisions on systems design for efficient energy use and energy management as it requires closer collaboration with the hospital and healthcare facility owners and operators. It is hoped that the next edition will contain significant and substantial discussions on energy use of mechanical systems.

The manual is a testament to the genuine contribution of the mechanical engineering practitioners to the upliftment and the furtherance of mechanical systems for vital facilities such as hospitals and healthcare facilities.

The Board of Mechanical Engineering (2020)
The Technical Working Group for Hospital and Healthcare Facility Standards (2020)

1.0 HEATING, VENTILATION, AND AIR CONDITIONING (HVAC) SYSTEMS

1.1 GENERAL CONSIDERATIONS

In hospitals and healthcare facilities, HVAC systems play a vital role beyond the mere promotion of comfort. Air-conditioning is an essential factor in patient therapy;in some instances, it is theprimary treatment. Ventilation system requirements exist to protect against harmful occupational exposures by providing clean air through exchanging indoor and outdoor air and filtering. During the height of the Covid-19 pandemic, various researchers concluded that increased transmission of respiratory infections could be attributed to poorly ventilated and unventilated indoor spaces.

The fundamental differences between air-conditioning for hospitals and related healthcare facilities and that of the other building types stem from the following;

1. Need to restrict air movement in and between departments or spaces.
2. Specific Requirements for Ventilation and Filtration to dilute and remove contamination (odor, airborne microorganism and viruses, hazardous chemicals and radioactive substances.
3. Different temperature and humidity requirements for various areas
4. Design sophistication needed for accurate control of environmental conditions.

While the need for clean and conditioned air in hospital & health care facilities is high, the relatively high cost of air-conditioning demands efficient design and operation to ensure economical management. In addition, The Philippine Green Building Code calls for & mandates the adoption of efficient practice design, methods, and technologies that reduce energy consumption for buildings, including hospital and healthcare facilities.

The aim of this manual is to provide general guidelines for designing HVAC systems for new healthcare facilities and, to a significant extent, for recommendations for facility renovations and construction in existing buildings.

1.2 DESIGN CONSIDERATIONS

1.2.1 Outdoor Climatic Design Conditions

1.2.1.1 The outdoor climatic design conditions can be obtained from the ASHRAE Climatic database or other local data sources. The design conditions should be carefully evaluated, especially the wet bulb temperature, in case of worse case air intake for outside air. The following are the recommended outdoor design conditions for the following locations;

(a) Metro Manila External Conditions:

35 deg C db1, 27.2 deg C wb2 at 1% degree days.

(b) Other Regions or Locations:
Refer to the Latest ASHRAE Handbook Fundamentals 2019 or ASHRAE 90.1.2010.

1.2.2 Building Envelope Design Criteria

1.2.2.1 The building envelope criteria in Table M-1.0 shall be adopted for Hospital & healthcare facilities applicable for new construction and major renovation projects. The Mechanical Engineer -HVAC Specialist in charge of the design shall coordinate with the Architect /Owner, ensuring that the design of the building envelope shall follow and not exceed the recommended Maximum U-Values and Building Envelope Insulation minimum R-Rating.

It is encouraged to improve upon the recommended values for medium to large healthcare facilities running

24/7 operation as they consume the most energy as compared to any other building type.

Table 1.1 | BUILDING ENVELOPE DESIGN CRITERIA

BUILDING COMPONENT	ASSEMBLY U – VALUE (Maximum)	Insulation Minimum R-Value
Metal Roof [(1)]	0.35 W/m²-K	R-19
Roof Deck [(1)]	0.36 W/m²-K	R-15
External Walls (CMU)	3.20 W/m²-K	Optional
Walls (Metal)	0.53 W/m²-K	R-16
Floor (including basement floors)	1.8 W/m²-K	R-15
Doors	Swing Doors - 0.74 W/m²-K Non-swing doors – 1.45	NR
Vertical Fenestration (Full assembly)	**Refer to Table 1-2**	NR

Key Notes:
Solar Reflectance Index (SRI) > 78
Refer to an acoustic consultant for acoustic requirements.
NR – Not Required

Table 1-2 | SHGC & VLT FOR DIFFERENT WWR

WWR	Maximum SHGC	Minimum VLT
10	0.80	0.80
20	0.70	0.70
30	0.60	0.70
40	0.40	0.60
50	0.35	0.55
60	0.30	0.50
70	0.28	0.45
80	0.25	0.40

1.2.3 Design Internal Conditions (Space Temperature and Relative Humidity)

1.2.3.1 Healthcare facilities' internal conditions will be categorized into clinical and non-clinical spaces. All spaces that directly affect patient care will be categorized in this guideline as clinical spaces. If additional regulatory or organizational criteria exist, refer to those criteria for specific space requirements. Close coordination with health care planners and medical equipment specialists in the mechanical design and construction of hospital & healthcare facilities is essential to achieve the desired conditions. Identified below are the performance levels for internal spaces.

Table 1-3 Criteria for Clinical Spaces

Criteria	Requirements
Temperature	Internal design temperatures shall be in accordance with Table 1-5. If there is an equipment-specific space temperature requirement, it may supersede the listed requirements.
Relative Humidity	Internal relative humidity shall generally be in accordance with Table 1-5. If there is equipment with a specific room relative humidity requirement, it may supersede the listed requirements.
Lighting Power Density	Lighting loads shall be based on an average watts/m² figure for each type of room based on a representative lighting layout. General guidance can be obtained from ASHRAE 90.1.2016 Lighting Power Density or as prescribed in the Philippine Green Building Code.
Medical Equipment Power Load	Medical equipment heat dissipation loads shall be based on the values listed in the Room Data Sheets (RDS). RDS values should represent actual equipment heat dissipation values using 'worst case' manufacturer's published data from the range of potential suppliers.
Occupancy	Design occupancy for each space shall be as specified per actual design requirements. If no occupancy is provided, the design shall be based on local code requirements or ASHRAE 62.1, whichever is more stringent.
Infiltration	The building should be designed to be at positive pressure with respect to the atmosphere at all times. Infiltration load should only be considered for high-rise.
Ventilation	The minimum requirements for ventilation shall be as specified in Section 1.3 of these guidelines. For spaces not listed, you may refer to ASHRAE 170 or ASHRAE 62.1.
Acoustic Requirements	The design for HVAC system should follow the acoustic requirements listed in Table 1 of the 2019 ASHRAE Handbook of Applications.

Table 1-4 Criteria for Non-Clinical Spaces

Criteria	Requirements
Temperature	Internal design temperatures shall be in accordance with Table M-3. If there is an equipment-specific space temperature requirement, it may supersede the listed requirements.
Relative Humidity	Internal relative humidity shall generally be in accordance with Table M-2. The Mechanical Engineer should ensure that maximum relative humidity is kept within the specified range by employing localized humidity control equipment or BMS control algorithm.
Lighting Power Density	Lighting loads shall be based on an average watts/m2 figure for each type of room based on a representative lighting layout. General guidance can be obtained from ASHRAE 90.1.2016 Lighting Power Density or as the Philippine Green Building defines.
Electrical Small Power	Where there are specific equipment rooms, the heat loads shall be based on the 'worst case' values from the potential range of suppliers. Where there are no particular equipment layouts, allowances for small power loads shall be made on an average watts/m2 basis as appropriate for the space type. Refer to ASHRAE Handbook Fundamentals 2017 Chapter 18 Non-residential cooling loads.
Occupancy	The design shall be based on the furniture layout or as per local code requirements. ASHRAE 62.1 can also be used as a reference, whichever is more stringent.
Infiltration	The building should be designed to be at positive pressure with respect to the atmosphere.
Ventilation	The minimum requirements for ventilation shall be as specified in the ASHRAE Standard 62.1.2016.
Acoustic Requirements	The design for the HVAC system should follow the acoustic requirements per hospital requirements.

Table 1-5 Indoor Design Conditions for Clinical Areas

ASHRAE 170-2013

FUNCTIONAL SPACES	DESIGN DRY BULB TEMPERATURE [(l)] (°F / °C)	RELATIVE HUMIDITY [(k)]	Air Recirculated by Means of Room Units [(a)]
SURGERY AND CRITICAL CARE			
Classes B and C operating rooms [(m),(n),(o)]	68-75/20-24	40-60	No
Operating surgical cystoscopic rooms [(m),(n)]	68-75/20-24	40-60	No
Delivery room [(m),(n), (o)]	68-75/20-24	40-60	No
Substerile service area	N/R	N/R	No
Recovery room	70-75/21-24	40-60	No
Critical and intensive care	70-75/21-24	40-60	No
Wound intensive care (burn)	70-75/21-24	40-60	No
Newborn intensive care	70-75/21-24	30-60	No
Treatment room [(p)]	70-75/21-24	30-60	N
Trauma room (crisis or shock)	70-75/21-24	30-60	No
Medical/anesthesia gas storage ®	N/R	N/R	N/R
Laser eye room	70-75/21-24	30-60	No
ER waiting room [(q)]	70-75/21-24	max 65	N/R
Triage	70-75/21-24	max 60	N/R
ER decontamination	N/R	N/R	No
Radiology waiting rooms [(q)]	70-75/21-24	max 60	N/R
Class A operating/Procedure room [(o), (d)]	70-75/21-24	30-60	No
STERILIZING			
Sterilizer equipment room	NR	NR	No
RADIOLOGY [(v)]			
X-ray (diagnostic and treatment)	72-78/22-26	max 60	N/R
X-ray (surgery/critical care and catherization)	70-75/21-24	max 61	No
Darkroom [(g)]	N/R	N/R	No

INPATIENT NURSING			
Patient room(s)	70-75/21-24	max 60	N/R
Toilet room	N/R	N/R	No
Newborn nursery suite	72-78/22-26	30-60	No
Protective environment room (f), (n), (t)	70-75/21-24	max 60	No
AII room (e), (n), (u)	70-75/21-24	max 60	No
AII isolation anteroom (t), (u)	N/R	N/R	No
Labor/delivery/recovery/postpartum (LDR) (s)	70-75/21-24	max 60	N/R
Labor/delivery/recovery (LDR) (s)	70-75/21-24	max 60	N/R
Corridor	N/R	N/R	N/R
SKILLED NURSING FACILITY			
Resident room	70-75/21-24	N/R	N/R
Resident /gathering/ activity/ dining	70-75/21-24	N/R	N/R
Physical therapy	70-75/21-24	N/R	N/R
Occupational therapy	70-75/21-24	N/R	N/R
Bathing Room	N/R	N/R	N/R
SERVICE			
Food preparation center (i)	72-78/22-26	N/R	No
Warewashing	N/R	N/R	No
Dietary storage	72-78/22-26	N/R	No
Laundry, general	N/R	N/R	No
Soiled linen sorting and storage	N/R	N/R	No
Clean linen storage	72-78/22-26	N/R	N/R
Linen and trash chute room	N/R	N/R	No
Bedpan room	N/R	N/R	No
Bathroom	72-78/22-26	N/R	No
Janitor's closet	N/R	N/R	No
SUPPORT SPACE			
Soiled workroom or soiled holding	N/R	N/R	No
Clean workroom or clean holding	N/R	N/R	N/R
Hazardous material storage	N/R	N/R	No

DIAGNOSTIC AND TREATMENT			
Bronchoscopy/ sputum collection and pentamidine administration (n)	68-75/20-24	N/R	No
Laboratory, general (v)	70-75/21-24	N/R	No
Laboratory, bacteriology (v)	70-75/21-24	N/R	No
Laboratory, biochemistry (v)	70-75/21-24	N/R	No
Laboratory, cytology (v)	70-75/21-24	N/R	No
Laboratory, glass washing	N/R	N/R	No
Laboratory, histology (v)	70-75/21-24	N/R	No
Laboratory, microbiology (v)	70-75/21-24	N/R	No
Laboratory, nuclear medicine (v)	70-75/21-24	N/R	No
Laboratory, pathology (v)	70-75/21-24	N/R	No
Laboratory, serology (v)	70-75/21-24	N/R	No
Laboratory, sterilizing (v)	70-75/21-24	N/R	No
Laboratory, media transfer (v)	70-75/21-24	N/R	No
Autopsy room (n)	68-75/20-24	N/R	No
Non-refrigerated body-holding room (h)	70-75/21-24	N/R	No
Pharmacy (b)	N/R	N/R	N/R
Examination room	70-75/21-24	max 60	N/R
Medication room	70-75/21-24	max 60	N/R
Endoscopy	68-75/20-24	30-60	No
Endoscope cleaning	N/R	N/R	No
Treatment room	70-75/21-24	max 60	N/R
Hydrotherapy	72-78/22-26	N/R	N/R
Physical therapy	72-78/22-26	Max 65	N/R
CENTRAL MEDICAL AND SURGICAL SUPPLY			
Soiled or decontamination room	72-78/22-26	N/R	No
Clean workroom	72-78/22-26	max 60	No
Sterile storage	72-78/22-26	max 60	N/R

Table 1-5 Indoor Design Conditions for Non-Clinical Areas

ASHRAE 170-2013

FUNCTIONAL SPACES	DESIGN DRY BULB TEMPERATURE [l] (°C)	RELATIVE HUMIDITY [k]	Air Recirculated by Means of Room Units [a]
Administration Offices	23 deg C +/- 1 deg C	55% +/- 5%	Yes
Main Lobby	23 deg C +/- 1 deg C	55% +/- 5%	
Waiting Area	23 deg C +/- 1 deg C	55% +/- 5%	
Fire Comment center	23 deg C +/- 1 deg C	55% +/- 5%	
Elevator Machine Room	23 deg C +/- 1 deg C	55% +/- 5%	
Common MDF Room	23 deg C +/- 1 deg C	55% +/- 5%	
Telco Provide Room	23 deg C +/- 1 deg C	55% +/- 5%	
Server Room (POS)	23 deg C +/- 1 deg C	55% +/- 5%	
Security Room (Barracks)	24 deg C +/- 1 deg C	55% +/- 5%	
Housekeeping Room	24 deg C +/- 1 deg C	55% +/- 5%	
Technical Maintenance Room	24 deg C +/- 1 deg C	55% +/- 5%	
Grounds Maintenance Room	24 deg C +/- 1 deg C	55% +/- 5%	
Pest Control Room	24 deg C +/- 1 deg C	55% +/- 5%	
Concierge Room	24 deg C +/- 1 deg C	55% +/- 5%	
Bio Augmentation Room	24 deg C +/- 1 deg C	55% +/- 5%	
Concierge Room	24 deg C +/- 1 deg C	55% +/- 5%	
Parking Teller Room	24 deg C +/- 1 deg C	55% +/- 5%	
Bio Augmentation Room	24 deg C +/- 1 deg C	55% +/- 5%	
LPG Room / Office	24 deg C +/- 1 deg C	55% +/- 5%	
FDAS	24 deg C +/- 1 deg C	55% +/- 5%	
Retail Food Merchants	24 deg C +/- 1 deg C	55% +/- 5%	
Meeting Rooms	23 deg C +/- 1 deg C	55% +/- 5%	

1.2.4 Noise Criteria

1.2.4.1 Noise control is highly important in the healthcare environment because of the negative impact of high noise levels on patients and staff and the need to safeguard patient privacy. The typical healthcare facility is already full of loud noises from various communications equipment, alarms, noisy operating hardware, and other causes without the noise contribution from poorly designed or installed HVAC equipment. High noise levels largely hinder patient healing through interference with rest and sleep. In addition, loud noises degrade the healthcare provider's working environment, increase stress, and can cause dangerous irritation and distraction during critical activities. Sources of excessive HVAC noise include;

- direct transmission of mechanical and/or medical equipment room noise to adjacent spaces;
- duct-borne noise generated by fans and/or high air velocities in ducts, fittings, terminal equipment, or diffusers and transmitted through ductwork to adjoining occupied spaces;
- duct breakout noise, where noise in ductwork penetrates the walls of the duct and enters occupied spaces;
- duct rumble, a form of low-frequency breakout noise caused by the acoustical response of ductwork to fan noise—particularly high-aspect-ratio, poorly braced rectangular ductwork; and
- vibrations from fans, dampers, ductwork, etc.

Patient privacy can be compromised when private conversations are intelligibly transmitted to adjoining spaces. Frequent causes of this problem are inadequate acoustical isolation properties of the construction elements separating rooms, effective sound-dampening ductwork provisions, and/or insufficient background room sound pressure level. HVAC ductwork design and diffuser/register selection can significantly mitigate the latter two concerns by providing a minimum level of background sound contribution from the air distribution system and effective attenuation in ductwork.

In many cases, fan noise attenuation will be needed to achieve the room background noise levels required by design criteria. This is often a concern with the double-walled AHUs required for health care facilities because the interior sheet metal wall resists noise breakout and helps to transmit the noise through the duct-work. Providing sidewall takeoffs where diffusers connect to ductwork and adding flexible ductwork with at least one elbow at the final diffuser or grille connections can offer significant attenuation.

The designer's options include active electronic silencers or factory-fabricated sound attenuators when additional attenuation is required. Packless-type attenuators and active silencers have limited application and efficacy, often leaving packed-type liners and attenuators as the only practical choice. This chapter has already discussed concerns regarding water-permeable, unsealed insulation surfaces exposed to the airstream. Several manufacturers, however, offer double-walled attenuating ductwork or fabricated attenuators with perforated inner sheet metal housings and impermeable foil or plastic liners, which probably offer the best compromise between durability/sanitation concerns and the need for noise attenuation. Such foil or plastic liners do not drastically reduce attenuation performance. However, their flame spread/smoke generation characteristics should be checked against the limiting requirements of NFPA 90A and applicable codes. Because of installation space limitations and to improve the inspectability and cleanability of airflow surfaces, fabricated attenuators are often chosen over attenuating ductwork.

1.3 HVAC SYSTEMS FOR AIRBORNE INFECTION CONTROL

1.3.1 Ventilation

1.3.1.1 The control of air pollutants is a combination of dilution ventilation and contaminant exhaust. This way, the concentration level of airborne contaminants is reduced. Dilution ventilation is the process of supplying relatively contaminant-free outdoor make-up air.

1.3.1.2 The ventilation rates in Table 2-1 of ese guidelines are minimums that control environmental comfort, asepsis, and odor control. These minimum requirements do not offer assured protection from discomfort, airborne transmission of contagions, and odors.

Table 1.3-1: Minimum Ventilation Rates
From ASHRAE 170-2013

Space Function	Pressure Relationship to Adjacent Areas	Minimum Outdoor Air, ACH	Minimum Total Air, ACH	All Room Air Exhausted Directly to Outdoors	Air Recirculated By Means of Room Units
Surgery and Critical Care					
Operating Room (Class B and Class C)	Positive	4	20	NR	No
Operating/surgical cystoscopic room	Positive	4	20	NR	No
Delivery Room	Positive	4	20	NR	No

Substerile Service Area	NR	2	6	NR	No
Recovery Room	NR	2	6	NR	No
Critical and Intensive Care	NR	2	6	NR	No
Immediate Care	NR	2	6	NR	NR
Wound Intensive Unit (Burn Unit)	NR	2	6	NR	No
Newborn Intensive Care Unit	Positive	2	6	NR	No
Treatment Room	NR	2	6	NR	NR
Trauma Room (crisis or shock)	Positive	3	15	NR	No
Medical Anesthesia/Gas Storage	Negative	NR	18	Yes	NR
Laser Eye Room	Positive	3	15	NR	No
Emergency Room Waiting Areas	Negative	2	12	Yes	NR
Triage	Negative	2	12	Yes	NR
ER Decontamination	Negative	2	12	Yes	No
Radiology waiting Rooms	Negative	2	12	Yes	NR
Procedure Room (Class A surgery)	Positive	3	15	NR	No
Emergency Department Exam/ Treatment Room	NR	2	6	NR	NR
Inpatient Nursing					
Patient Room	NR	2	4	NR	NR
Nourishment Area	NR	NR	2	NR	NR
Toilet	Negative	NR	10	Yes	No
Newborn Nursery Suite	NR	2	6	NR	No
Protective Environment Room	Positive	2	12	NR	No
AII Room	Negative	2	12	Yes	No
Combination AII/PE Room	Positive	2	12	Yes	No
AII Anteroom	See Sect. 2.1.2.2.5	NR	10	Yes	No
PE Anteroom	See Sect. 2.1.2.2.4	NR	10	NR	No
Combination AII/PE Room	See Sect. 2.1.2.2.6	NR	10	Yes	No
Labor/Delivery/Recovery/Postpartum (LDRP)	NR	2	6	NR	NR
Labor/Delivery/Recovery (LDR)	NR	2	6	NR	NR
Patient Corridor	NR	NR*	2	NR	NR
Nursing Facility					
Resident Room	NR	2	2	NR	NR
Resident activity/dining	NR	4	4	NR	NR
Resident Unit Corridor	NR	NR*	4	NR	NR
Physical Therapy	Negative	2	6	NR	NR
Occupational Therapy	NR	2	6	NR	NR
Bathing Room	Negative	NR	10	Yes	No
Radiology					
X-ray (diagnostic and treatment)	NR	2	6	NR	NR

X-ray (surgery/critical care/ catheterization)	Positive	3	15	NR	No
Darkroom	Negative	2	10	Yes	No
Diagnostic and Treatment					
Bronchoscopy, sputum collection, and pentamidine administration	Negative	2	12	Yes	No
Laboratory, general	Negative	2	6	NR	NR
Laboratory, bacteriology	Negative	2	6	Yes	NR
Laboratory, biochemistry	Negative	2	6	Yes	NR
Laboratory, cytology	Negative	2	6	Yes	NR
Laboratory, glass washing	Negative	2	10	Yes	NR
Laboratory, histology	Negative	2	6	Yes	NR
Laboratory, microbiology	Negative	2	6	Yes	NR
Laboratory, nuclear medicine	Negative	2	6	Yes	NR
Laboratory, pathology	Negative	2	6	Yes	NR
Laboratory, serology	Negative	2	6	Yes	NR
Laboratory, sterilizing	Negative	2	10	Yes	NR
Laboratory, media transfer	Positive	2	4	NR	NR
Non-refrigerated body holding room	Negative	NR	10	Yes	No
Autopsy Room	Negative	2	12	Yes	No
Pharmacy	Positive	2	4	NR	NR
Examination Room	NR	2	6	NR	NR
Medication Room	NR	2	4	NR	NR
Gastrointestinal endoscopy procedure room	NR	2	6	NR	No
Endoscope cleaning	Negative	2	10	Yes	No
Treatment Room	NR	2	6	NR	NR
Hydrotherapy	Negative	2	6	NR	NR
Physical Therapy	Negative	2	6	NR	NR
Dialysis Treatment Area	NR	2	6	NR	NR
Dialyzer reprocessing room	Negative	NR	10	Yes	No
Nuclear hot lab	Negative	NR	6	Yes	No
Nuclear medicine treatment room	Negative	2	6	Yes	NR
Sterilizer Equipment Room	Negative	NR	10	Yes	No
Central Medical and Surgical Supply					
Soiled or decontamination room	Negative	2	6	Yes	No
Clean Workroom	Positive	2	4	NR	No
Sterile Storage	Positive	2	4	NR	NR
Service					
Food preparation center	NR	2	10	NR	No
Ware washing	Negative	NR	10	Yes	No
Dietary Storage	NR	NR	2	NR	No
Laundry, general	Negative	2	10	Yes	No
Soiled line sorting and storage	Negative	NR	10	Yes	No

Clean linen storage	Positive	NR	2	NR	NR
Linen and trash chute room	Negative	NR	10	Yes	No
Bedpan room	Negative	NR	10	Yes	No
Bathroom	Negative	NR	10	Yes	No
Janitor's closet	Negative	NR	10	Yes	No
Support Space					
Soiled workroom or soiled holding	Negative	2	10	Yes	No
Clean workroom or clean holding	Positive	2	4	NR	NR
Hazardous material storage	Negative	2	10	Yes	NO

NR - Not Required

1.3.1.3 For design purposes, the minimum number of air changes indicated shall be supplied for positive pressure rooms or exhausted for negative pressure rooms. Spaces that are required in Table 2-1 to be negative pressure but not required to be exhausted shall utilize the supply air flow rate to compute the minimum total air changes per hour required. For spaces that require a positive or negative pressure relationship, the number of air changes can be reduced when the space is unoccupied, provided that the required pressure relationship to the adjoining spaces is maintained while the space is unoccupied and that the minimum number of air changes indicated is re-established anytime the space becomes occupied. Air change rates in excess of the minimum values are expected in some cases to maintain room temperature and humidity conditions based on the space cooling load.

1.3.1.4 For spaces where Table 1.3-1 permits recirculation of air by room units, the portion of the minimum total air changes per hour required for the space that is greater than the minimum outdoor air required component may be provided by recirculating room HVAC units. Such recirculating HVAC units shall:

1.3.1.5 For air handling systems serving multiple spaces, minimum system outdoor air quantity shall be calculated using either of the following methods:

a. System minimum outdoor air quantity for an air handling system shall be calculated as the sum of the individual space requirements indicated in Table 2-1.
b. System minimum outdoor air quantity shall be calculated using the Ventilation Rate Procedure (multi-zone formula) of ASHRAE 62.1-2019. The minimum outdoor air change rate listed in Table 2-1 shall be interpreted as the Voz (zone outdoor air flow) for the purposes of this calculation method.

1.3.1.6 More specific design guidelines are provided from the following references:

a. ANSI/ASHRAE/ASHE 170-2013 Ventilation of Health Care Facilities
b. CDC 2003 Guidelines for Environmental Infection Control in Health-Care Facilities
c. ASHRAE 2003 HVAC Design Manual For Hospitals and Clinics

1.3.2 Room Pressure Gradients and Air Flow Patterns

1.3.2.1 Directional air flow is the control of airflow into or out of a room or unidirectionally through a defined "clean" area of a room. Directional air flow has three major applications:

a. Establishment of directional airflow into or out of one space or spaces adjoining. The establishment of a relative differential pressure between spaces achieves the directional air flow. Directional airflow out of space, or positive relative pressurization, is utilized when there is a need to protect room occupants or materials from airborne contaminants outside the space. Air flow into a space (negative pressurization) is utilized when it is desired to prevent contaminants released in the space from spreading to adjoining areas. The achievement of the specific room pressure differential relative to surrounding spaces is dependent not only on the supply-return/exhaust configuration but also upon the air tightness of the room's construction. A generally accepted practice to ensure the achievement of directional airflow between spaces is the establishment of a minimum of 2.5 Pa pressure differential.

b. Within rooms, directional airflow may be achieved to a limited extent with low-velocity, non-aspirating supply diffusers that project unidirectional flow for a distance into a space. This arrangement provides a laminar stream of clean air to remove or exclude contaminants from a clean zone, to be extracted at strategically located exhaust or return air openings.

c. Directional airflow is also the principle utilized in laboratory fume hoods, biosafety cabinets, and other specially manufactured protective ventilation equipment. The equipment is usually designed to establish a relatively high flow velocity (about 0.5 m/s or 100 fpm) over the working surface, sufficient to transport and remove aerosolized contaminants from a personnel's breathing zone.

1.3.2.2 If any form of variable air volume or load-shedding is used for energy conservation, it shall not compromise the pressure balancing relationships or the minimum air changes required in Table 2-1.

1.3.2.3 Room pressure relationships and directional flow requirements for special care areas shall be as stated in Table 2-2 below:

Table 1.3-2 Specifications for Positive- and Negative- Pressure Rooms

2003 CDC Guidelines for Environmental Infection Control for Health-Care Facilities

Engineered specifications for positive- and negative pressure rooms*		
Engineering characteristics	**Positive pressure areas (e.g., protective environments [PE])**	**Negative pressure areas (e.g., airborne infection isolation [AII])**
Pressure differentials	**> +2.5 Pa§ (0.01" water gauge)**	**> -2.5 Pa (0.01" water gauge)**
Air changes per hour (ACH)	**> 12**	**≥ 12 (for renovation or new construction)**
Filtration efficiency	**Supply : 99.97% @ 0.3µm DOP (dioctyl phthalate particles of 0.3µm diameter) Return: none required (If the patient requires both PE and AII, return air should be HEPA-filtered or otherwise exhausted to the outside)**	**Supply : 90% (dust spot test) Return: 99.97% @ 0.3µm DOP (dioctyl phthalate particles of 0.3µm diameter) HEPA filtration of exhaust air from AII rooms should not be required, providing that the exhaust is properly located to prevent re-entry into the building.**
Room airflow direction	**Out to the adjacent area**	**In to the room**
Clean-to-dirty airflow in room	**Away from the patient (high-risk patient, immunosuppressed patient)**	**Towards the patient (airborne disease patient)**
Ideal pressure differential	**> + 8 Pa**	**> -2.5 Pa**

1.3.2.4. Airborne Infection Isolation (AII) rooms shall have the following specific requirements:

a. All rooms shall comply with the requirements in Tables 2-1, 2-2, 2-3. All rooms shall have a permanently installed device to constantly visually monitor the differential pressure between the room and the corridor regardless of whether there is an anteroom or none.

b. Differential pressure between the AII rooms and the adjacent spaces that are not AII rooms shall be a minimum of -2.5 Pa (-0.1"w.g.). If an anteroom is provided, the pressure relationships shall be as follows: 1) AII is negative to the anteroom, 2) the anteroom is negative with respect to the adjoining corridor. The toilet or bathroom present in the AII shall be negative with respect to the AII.

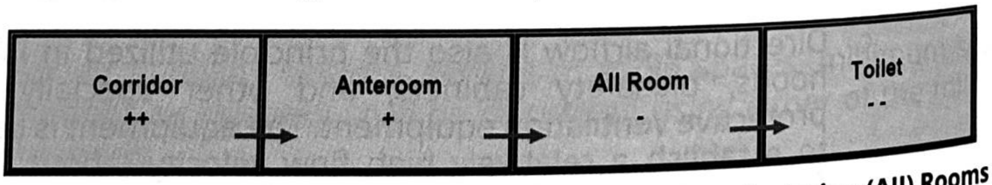


Fig. 1.3-1 Pressure Gradient for Airborne Infection Isolation (AII) Rooms

c. All exhaust air from the AII room, toilet, and anteroom shall be discharged directly to the outdoors without mixing with exhaust air from other non-AII room or exhaust system.

d. Exhaust air grilles shall be located directly above the patient bed on the ceiling or on the wall near the bed of the head.

1.3.2.5. Protective Environment (PE) Rooms shall have the following specific requirements:

a. PE rooms shall comply with the requirements in Tables 2-1, 2-2, and 2-3. All rooms shall have permanently installed devices to visually monitor the differential pressure between the room and the corridor, whether or not there is an anteroom.

b. Differential pressure between the AII rooms and the adjacent spaces that are not AII rooms shall be a minimum of +2.5 Pa (+0.1"w.g.). If an anteroom is provided, the pressure relationships shall be as follows: 1) PE room shall be positive to the anteroom, 2) the anteroom shall be positive with respect to the adjoining corridor. The toilet or bathroom present in the PE room shall be negative with respect to the PE room.

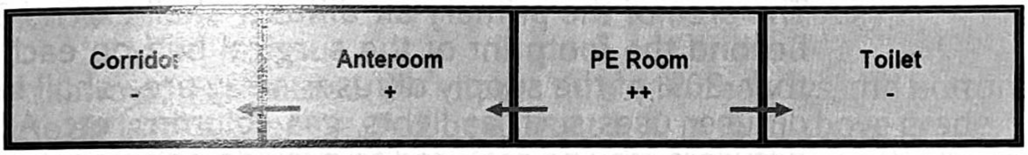


Fig. 1.3-2 Pressure Gradient for Airborne Infection Isolation (AII) Rooms

c. The supply air diffuser shall be above the patient bed. The diffuser design shall limit the air velocity at the patient bed to 0.2 m/s (40 fpm) to reduce patient discomfort. (See ASHRAE Standard 55-2013). The exhaust grille shall be located near the patient room door.

1.3.2.6. Combination Airborne Infection Isolation/Protective Environment (AII/PE) Room

a. Supply air diffusers shall be located above the patient bed. Exhaust grilles shall be located near the patient room door.

b. The pressure relationship to the adjacent areas shall either be of the following:

b.1. The anteroom shall be positive with respect to both the AII/PE room and the common space, or,

b.2 The anteroom shall be negative with respect to both the AII/PE room and the common space.

c. AII/PE rooms shall have two permanently installed visual monitoring devices. One device shall monitor the pressure differential between the AII/PE Room and the anteroom. The second device shall monitor the pressure differential between the anteroom and the adjoining corridor or general space.

1.3.2.7. Class B and C Operating Rooms/Surgical Cystoscopy Room/ Caesarean Delivery Room

a. The rooms shall be maintained at a positive pressure with respect to all adjoining spaces at all times. A pressure differential shall be maintained at a value of at least 2.5 Pa (0.1 in. w.g.). Each room shall have individual temperature control.

b. The air flow shall be unidirectional, downwards, and the average velocity of the diffusers shall be 125 to 180 L/s/m² (25 to 35 cfm/ft²). The diffusers shall be concentrated to provide an airflow pattern over the patient and surgical team (Memarzadeh and Manning, 2002; Memarzadeh and Jiang, 2004)

c. The area of the primary air diffuser shall extend 300 mm (12 in.) beyond the footprint of the surgical bed on each side. No more than 30% of the supply diffuser array area shall be used for non-diffuser uses such as lights, gas columns, etc. Additional supply diffusers may be required to provide additional ventilation to the operating room to achieve environmental requirements in Table 1.2-1 and Table 1.3-1

d. The room shall be provided with at least two low sidewall return or exhaust grilles space at opposite corners or as far apart as possible, with the bottom of the grilles installed approximately 200 mm (8 in.) from the floor.

1.3.2.8 Morgue and Autopsy Rooms

a. Low-sidewall exhaust grilles shall be provided unless exhaust air is removed from the autopsy table for this purpose.

b. All exhaust air from the autopsy room, non-refrigerated body holding room, and morgue rooms shall be discharged directly to the outdoors without mixing with air from any other room or exhaust system.

c. Differential pressure between the morgue and autopsy rooms and adjacent areas that have other functions shall be a minimum of -2.5 Pa (0.1 in. w.g.).

1.3.2.9 Bronchoscopy

a. Differential pressure between bronchoscopy procedure, sputum induction rooms, and any other spaces with different functions shall be a minimum of -2.5 Pa (0.1 in. w.g.).

b. Local exhaust shall be provided for sputum collection procedures.

1.3.3 Contaminant Source Control

1.3.3.1 Outdoor Air

a. Outdoor air intakes for air handling units shall be at least 8 m (25 ft) from all cooling towers and exhaust and vent discharges. Outdoor air intakes shall be located such that the bottom of the air intake shall be at least 1.80 m (6 ft) above the grade. Outdoor air intakes on top of buildings shall be located with the bottom of the intake at a minimum of 1.0 m (3ft) above.

b. All intakes shall be designed to prevent the entrainment of wind-driven rain, shall contain features for draining away precipitation, and shall be equipped with a bird screen mesh of no smaller than 13mm.

c. Areaways: For outdoor air intakes through areaways, the bottom of the air intake opening shall be at least 1.80 m (6 ft) above grade. The bottom of the air intake opening from the areaway into the building shall be at least 1.0 m (3 ft) above the bottom of the areaway.

1.3.3.2 Exhaust Air

a. Ducts conveying air to be exhausted from AII rooms, bronchoscopy rooms, emergency department waiting rooms, nuclear medicine laboratories, radiology waiting rooms, all laboratory fume hoods, and, in general, Class 4 air as defined in ASHRAE 62.1-2019, shall be negatively pressurized relative to other ducts, plenums, and all spaces within the building.

b. Exhaust air from these rooms shall be discharged vertically at least 3 m (10 ft) above roof level.

c. Air discharge shall be at a distance in accordance with ASHRAE 62.1-2019, or not less than 3 m (10ft) from air intakes, openable windows, and doors, or areas that are normally accessible to the public or maintenance personnel and that are higher in elevation than the exhaust air discharge.

d. Exhaust air shall be directed to the outdoor and away from populated areas. Air to be discharged from AII and PE rooms shall pass through HEPA filters before they are exhausted to the outdoors.

e. Air exhaust from AII rooms or from combination AII/PE rooms shall not be used for energy recovery.

1.3.4 Filtration

1.3.4.1 Air filtration minimizes the build-up of particle concentrations in indoor environments. Particles have a tendency to become deposited either in the respiratory tract or lower respiratory tract, depending on the size (Morrow 1980).

1.3.4.2 Filter banks shall be provided in accordance with Table 1.3-3. Filter Bank No.1 shall be installed upstream of all cooling and heating coils, such that all air is mixed. Filter Bank No. 2 shall be installed downstream of wet cooling coils and supply fans.

Table 2-2 Minimum Filter Efficiencies

Patterned after ASHRAE 170-2013

Space Designation	Filter Bank No.1 (MERV)[a]	Filter Bank No.2 (MERV)
Operating Rooms (Class B and C surgeries) Inpatient delivery and recovery spaces, Inpatient and ambulatory diagnostic and therapeutic radiology	13	HEPA
Inpatient care, treatment, and diagnosis, Airborne Infection Isolation Areas (AII), and spaces providing direct service, or clean supplies and clean processing	13	HEPA
Protective Environment (PE) rooms	13	HEPA
Procedure Rooms (Class A surgery), Laboratories, and associated semi-restricted spaces	13	NR*
Nursing facilities	14	NR
Resident care, treatment, and support areas in inpatient hospice facilities	14	NR
Psychiatric Hospitals	14	NR
Administrative, Food preparation spaces	14	NR
Outpatient spaces	13	NR
Bulk storage, soiled holding spaces, laundries	8	NR

Notes: * - NR – Not Required

a. The minimum efficiency reporting value (MERV) is based on the method of testing described in ANSI/ASHRAE 52.2-2019 Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size.
b. Prefilters may be added to reduce maintenance of filters with efficiencies higher than MERV-7
c. MERV-14 filter may be used in Filter Bank No. 2 if a tertiary HEPA filter will be used to serve spaces.
d. High Efficiency Particulate Air (HEPA) filters are those filters that remove at least 99.97% of 0.3 micron particles at the rated flow in accordance with the testing methods of IEST RP-CC001.3 (IEST 2005)
e. Surgery procedure Classes A, B, C are as defined in the ASHRAE HVAC Design Manual For Hospitals and Clinics

1.3.4.3. Filter frames shall be metal and proportioned to provide an airtight fit with the enclosing ductwork. All joints between segments and the corresponding ductwork shall be gasketed and shall have a positive seal against air leakage.

1.3.4.4. Portable industrial-grade HEPA filters may be used to temporarily recirculate air inside the rooms in cases when there is no general ventilation, augment systems that cannot provide adequate air flow, and provide increased effectiveness in air flow.

1.3.4.5 If portable industrial-grade HEPA filters are used, they should be capable of recirculating all the room air through the HEPA filter. The unit shall be selected or designed to achieve the equivalent of 12 air changes per hour (ACH) as minimum.

1.3.5 Ultraviolet Germicidal Irradiation (UVGI)

1.3.5.1 Ultraviolet germicidal irradiation is that portion of the electromagnetic spectrum described by wavelengths from 200 to 270 nanometers (nm). UVGI is the use of ultraviolet radiation to kill or inactivate microorganisms. UVGI lamps may be used in ceilings, wall fixtures, or air ducts of ventilation systems.

1.3.5.2 Two UVGI systems may be used – upper room irradiation or duct irradiation. Upper room UVGI shall be unshielded above the unit to direct the irradiation upward. Duct irradiation system will require UV lamps to be installed inside ducts that extract air from room to disinfect the air before it is recirculated back into the space.

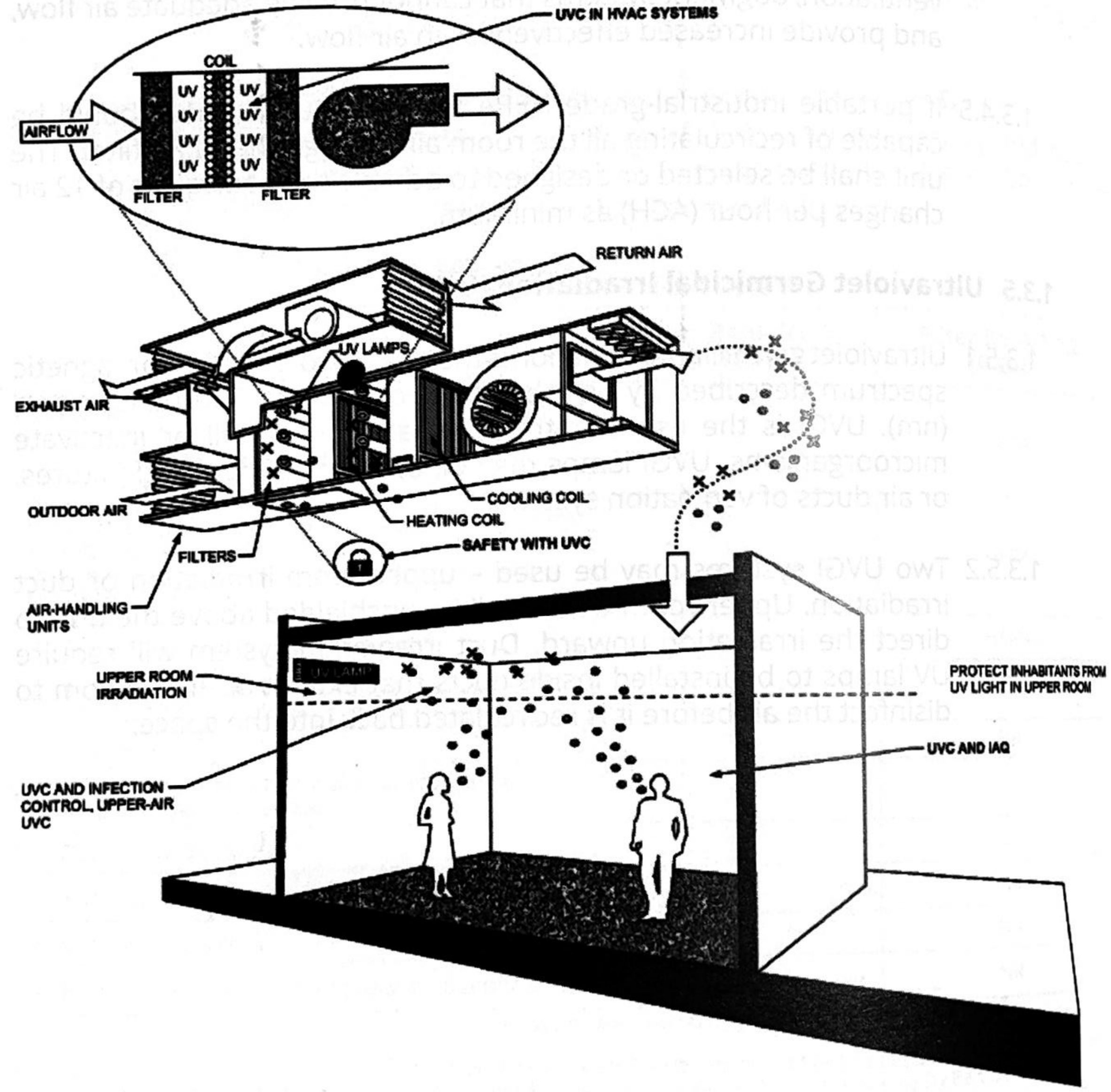

UVC IN HVAC SYSTEMS
COIL
UV
AIRFLOW
FILTER
FILTER
RETURN AIR
UV LAMPS
EXHAUST AIR
COOLING COIL
OUTDOOR AIR
HEATING COIL
SAFETY WITH UVC
FILTERS
AIR-HANDLING UNITS
UPPER ROOM IRRADIATION
UV LAMP
PROTECT INHABITANTS FROM UV LIGHT IN UPPER ROOM
UVC AND IAQ
UVC AND INFECTION CONTROL, UPPER-AIR UVC

Fig.1.3-3 Applications of UVGI in HVAC Systems and Upper Room Air
ASHRAE 2019 Handbook of HVAC Applications

1.3.5.3 The threshold limit value (TLV) for 254 nm is 6.0 μJ/cm² (ACGIH 2007) as determined by the American Conference of Governmental Industrial Hygienists (ACGIH).

1.3.5.4 UVGI shall not be permitted to be used for disinfecting air for recirculation from airborne isolation rooms. It shall not replace HEPA filters for exhaust air before its discharge to outdoors.

1.3.5.5 When UVGI lamps are installed in supply or return air ducts, AHU plenums, or upper room fixtures, designers must provide procedures that prevent accidental exposure of occupants and facilities maintenance personnel to unshielded UVGI.

1.3.5.6 Other safety procedures associated with the use of UVGI include procedures to be followed for the disposal of UVGI lamps that contain mercury, procedures to be followed if accidental breakage of UV lamps occurs; and training of facilities and maintenance personnel on hazards on the operations and maintenance of upper room lamps and UVGI in HVAC systems.

1.3.5.7 The installation, start-up, commissioning, and maintenance of UVGI systems may be referenced from the ASHRAE 2019 Handbook of Applications, Chapter 62, and the ASHRAE 2020 Handbook on HVAC Handbook and Equipment, Chapter 17.

1.4 EQUIPMENT AND AIR DISTRIBUTION CONSIDERATIONS

1.4.1 Basic HVAC Equipment Considerations

1.4.1.1 Air Handling Units

a. The casing of air handling units shall be designed to prevent water intrusion, resist corrosion, and permit access for inspection and maintenance. All airstream surfaces of air handling units shall comply with Section 5.4 of ANSI/ASHRAE 62.1-2019.
b. Air handling unit insulation shall be closed-cell material and shall be sandwiched in between metal sheets to minimize the possibility of dust collection and moisture that can provide a growth environment for dangerous microorganisms in the interior surfaces of the unit. Sheet metal surfaces also offer better cleanability of the interior surfaces of the AHU.
c. Outdoor air intakes must not be located near potential contaminant sources such as boiler and generator exhaust stacks, laboratory exhaust vents, plumbing vents, cooling towers, ambulance waiting and vehicle parking areas, loading pads, and helipads. The spacings may vary from 3 meters to 23 meters (10

ft to 75 ft), depending on the source's concentration and nature, the direction of the prevailing winds, and the building geometry.

i. All intakes should be equipped with a factory-fabricated louver designed to exclude wind-driven precipitation and with a bird screen to exclude birds and small mammals.

ii. Avoid placing an intake near horizontal surfaces that can cause rain splash to penetrate horizontally through the louver or can become a dangerous microbe growth source from collected bird droppings or other organic droppings.

d. Air mixing boxes shall allow the adequate mixing of outside and recirculated air.

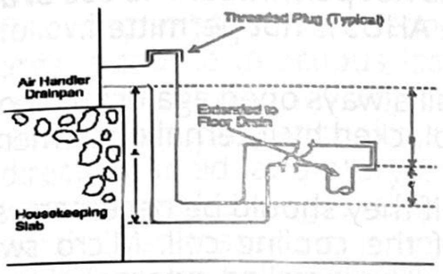
e. All air filters shall be provided with differential pressure gauges mounted on the air handling unit, reading differential static pressure across the filter to indicate when the filter will be changed. When the facility is provided with a central direct digital control (DDC) or Building Management System (BMS), filter pressure indication should also be available for monitoring and alarm generation on the system.

f. Access panels shall allow access to the upstream and downstream faces of all coils for cleaning or for straightening bent fins. The access and the panel door shall be large enough to enable maintenance personnel to access and to work on the entire face of the coil.

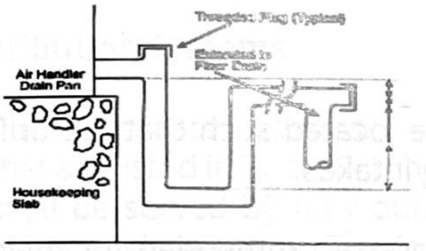
g. Cooling coils shall not exceed six (6) rows and shall have a maximum fin pitch of 2.56 mm per fin (10 fins per inch) to better remove dirt between fins and prevent excessive air pressure drop across the cooling coil. When additional rows are required, the cooling coils shall be split into two separate coils in the airflow direction.

In order to avoid the carryover of droplets from the cooling coil, the air velocity through the cooling coil must be limited. It is reasonable to size a cooling coil for a velocity lower than 2.3 m/s (450 feet per minute).

h. Cooling coils must be provided with positively draining pans constructed of stainless steel for the collection and disposal of condensate and to avoid standing water. The pan should reach entirely beneath the coil and extend approximately 300 mm (12 in.) from the coil discharge face. It shall be at least 50 mm (2 in.) deep with a drain pipe located so that the bottom of the drain pipe is flushed with the bottom of the pan. When coils are stacked vertically, a separately trapped drain pan should be provided for each coil.



Drain trap for coil subjected to negative pressure.



Drain trap for coil subjected to positive pressure.

Negative Pressure or Draw-Thru Configuration:
A = B + C
Where: B= static pressure + 1" w.g.
C = ½ B

Positive Pressure or Blow-Thru Configuration:
Trap Leg = A + B
A = AHU static pressure + ½ in
B = ½ in (minimum)

Fig. 1.4-1 Drain Trap Height for Draw-Thru and Blow-Thru AHU Configurations
ASHRAE HVAC Design Manual For Hospitals and Clinics

i. All air handling units shall be of the draw-thru type. Blow-thru air handling units shall not be permitted.

j. Operations and maintenance considerations shall be applied to the selection of an AHU supply fan to help ensure satisfactory long-term operation. Select the fans so that their normal operation will not be within the surge range. The specified motor size shall be sufficient for fan operation along a broad range of the fan operating curve.

k. Second filter banks shall be designed with air velocities that shall not exceed 2.5 m/s (500 fpm) for filters with efficiencies of MERV-15 or lower. HEPA filters and high-efficiency filters (MERV-16 and higher) should be designed with a maximum of 1.5 m/s (300 fpm).

    i. When calculating fan pressure requirements, the filter manufacturer's recommended final resistance shall be considered. If no final resistance recommendation is available, a value of 350 Pa (1.4 in. w.g.) is recommended for MERV 13-15 filters. It should be recognized that when filters are clean, the system resistance will be lower than the fan selection point. Thus, the fan must be properly sized to accommodate the higher brake horsepower requirements at that operating condition.

l. Each air handling unit shall be installed as a stand-alone unit without any interloping with another air handling unit. Stacking of AHUs one on top over the other, is not permitted. The use of a common return air fan for two or more AHUs is not permitted.

m. Access door panels shall always open against the positive side of the door and shall not be blocked by internal equipment components.

n. Ultraviolet (UV) lamps, if they should be necessary, shall be installed on the leaving side of the cooling coil. Micro switches or safety disconnect switches shall be installed external of the access panel of the UV lamp section to protect maintenance personnel from possible injuries.

1.4.1.2 Cooling Towers

a. Cooling towers shall be located such that the drift will be directed away from air handling intakes.

b. Stainless steel basins are recommended for their long service life and help in restricting microbial growth.

c. To minimize the potential for Legionellosis, professional help with chemical treatment is recommended. Drift eliminators should be regularly inspected, cleaned, and repaired as needed. It is a sound practice to alternate biocides used for cooling water treatment to avoid developing resistant strains of microbes.

1.4.1.3 Energy Recovery Units (Air-to-Air)

a. Energy recovery systems shall be installed upstream of Filter Bank No. 2. If energy recovery systems are utilized, the systems shall not allow for any cross contamination of exhaust air back to the main air stream via purge, leakage, carryover, or transfer.

b. Allowable methods of energy recovery include the following:

Table 1.4 Application of Energy Recovery Strategies

ASHRAE HVAC Design Manual For Hospitals and Clinics

Air-to-air Plate type Heat Exchangers	For areas where no cross-contamination is permitted
Total Energy Recovery Wheels	Allowed for general areas; shall not be allowed for All and PE rooms.
Run around coils	Allowed for all areas

c. Outside air energy recovery shall not be permitted from the following exhaust air streams: Emergency rooms, including triage area, airborne infectious isolation (AII) rooms, combination AII/PE rooms, radiology waiting rooms, darkrooms, sputum collection, and pentamidine administration, laboratory fume hoods and other directly ducted laboratory equipment exhaust, bio-safety cabinets, waste anesthesia gas disposal, autopsy, non-refrigerated body holding, endoscope cleaning, central medical and surgical supply soiled or decontamination rooms, laundry, hazardous material storage, dialyzer reprocessing room, nuclear laboratory and treatment rooms.

1.4.2 Air Distribution Systems

1.4.2.1 Room pressure relationships shall be maintained at all times. Spaces that are listed in Table 2-1 that have required pressure relationships shall be served by fully ducted return air systems or fully ducted exhaust air systems. The following additional surgery and critical-care patient-care areas that do not require pressure relationships with adjoining areas shall be served by fully ducted return air or exhaust air systems: (a) recovery rooms, (b) critical- and intensive-care areas, (c) immediate-care areas, (d) wound intensive care units. The air distribution system shall maintain space pressure relationships taking into account filter loading.

1.4.2.2 The air distribution system shall be provided with access doors, panels, and other means to allow convenient for inspection and cleaning. The specifications for constructing and installing duct access panels shall comply with the latest SMACNA Standards.

1.4.2.3 Air distribution devices shall be in accordance with the Table 1.4-1:

Table 1.4-2: Supply Air Outlets

ASHRAE 170-2013

Space Designation	Supply Air Outlet Classification [a]
Operating Rooms, Procedure Rooms (for all Class A, B, or C surgeries) [b]	Group E, non-aspirating
Protective Environment (PE) Rooms	Group E, non-aspirating
Wound Intensive Care (Burn Units	Group E, non-aspirating
Trauma Rooms	Group E, non-aspirating
Airborne Infection Isolation (AII) Rooms	Group A, or Group E
Single Bed Patient Rooms [c]	Group A, Group D, or Group E
All other patient care spaces	Group A, or Group E
All other spaces	No requirement

Notes:

(a) Refer to Chapter 20 of the 2017 ASHRAE Handbook Of Fundamentals

(b) Surgeons may require alternate distribution systems for specialized surgeries.

(c) For air distribution systems using Group D diffusers, system design shall be designed in accordance with the Design Guidelines in Chapter 7 of ASHRAE System Performance Evaluation and Design Guidelines for Displacement Ventilation.

1.4.2.4 Ducts that penetrate construction intended to protect x-ray, magnetic, and radio frequency interference (RFI) shall not impair the effectiveness of the protection, nor shall the treatment of these penetrations impair the ventilation of the spaces served.

1.4.2.5 An exterior vapor barrier shall be applied over thermal insulation on cold surfaces, especially for insulation materials that absorb or transmit moisture. The thickness of such insulation should result in the temperature of the insulated surface to be equal to or higher than the dewpoint temperature of the space in which the cold air duct is located.

1.4.2.6 Duct lining shall not be installed in ductwork located downstream of Filter Bank No.2.

1.4.3 HVAC System Instrumentation and Controls

1.4.3.1 Hospital and healthcare facility air conditioning plays a much more important role than simply providing comfort to patients and employees. Medical equipment in hospitals and healthcare facilities is sensitive to temperature and humidity levels and requires perfect control and instrumentation to function accurately. But also, the necessity of having rooms with very different uses in hospitals adds additional complexity to the design of these systems.

1.4.3.2 It is necessary to organize the different spaces and their use very clearly. In a hospital, it is essential to provide rooms where patients with various pathologies will be treated and rested, among a group that will be exposed to infectious-contagious diseases, which require a certain level of isolation, as well as rooms for patients with depressed or weak immune systems (such as intensive care rooms, or neonatal rooms, operating theaters), where it is necessary to prevent the arrival of pathogens that abound in hospitals. Hospitals are, therefore, places where a much higher concentration of pathogens accumulates than the average building and most of these agents travel in the air currents, making air conditioning equipment very sensitive to accumulating large quantities of pathogens and even serving as areas for their cultivation, with the consequent risk to the health of users. All this must be avoided with a correct design of the facilities so that patients, hospital workers, and visitors are protected from exposure to these pathogens.

1.4.3.3 Controls & Instrumentations are an essential part of any HVAC system. They provide a comfortable environment for patients, staff, and visitors; optimize energy cost and consumption; improve employee productivity; in some cases, may control smoke in the event of a fire; and control cooling for hospital equipment. Controls are essential for the proper and efficient operation of HVAC distribution systems and also for the proper and efficient operation of central plant equipment.

1.4.3.4 Automatic controls are used to maintain a setpoint for a controlled variable when disturbances cause a change in that variable. The most commonly controlled variables in HVAC systems are pressure, temperature, humidity, and flow rate.

1.4.3.5 Characteristics of the Control System

a. The consideration of fail-safe modes for HVAC systems and their controls is particularly important in health care facilities with patients who are not ambulatory. Control actuators have three different failure options — fail closed, fail open, and fail in place. In each case, the designer must consider the appropriate fail-safe mode.

b. The other important consideration for fail-safe mode involves a direct digital control (DDC) system that relies on a communications bus for data sharing. Careful consideration must be given to the mode of operation when, for example, the outdoor air temperature reading is lost. Likewise, prudent system design dictates that the inputs and outputs for a given control loop

b. Building Management System

b.1 a building management system (BMS) aims to centralize and simplify the monitoring, operation, and management of HVAC systems. BMS functions in health care facilities typically include;

- monitoring environmental conditions, systems, and plants;
- centralized alarm reporting;
- reducing energy use and cost through centralized control of energy-consuming systems;
- data trending;
- providing historical records; and
- supporting maintenance management programs.

b.2 Using a centralized system with network communications and user-defined limits for comfort conditions, simultaneously optimizing comfort and energy consumption is possible.

b.3 Modern DDC networks often use a facility's Ethernet local area network (LAN) for communication. Although this is usually a simple matter, caution must be exercised to ensure no bandwidth or security issues are associated with this approach. For example, very high-bandwidth transmissions (such as medical images) can cause traffic delays. The control system must be capable of handling such interruptions. The most critical security issue is to ensure the protection of patient data.

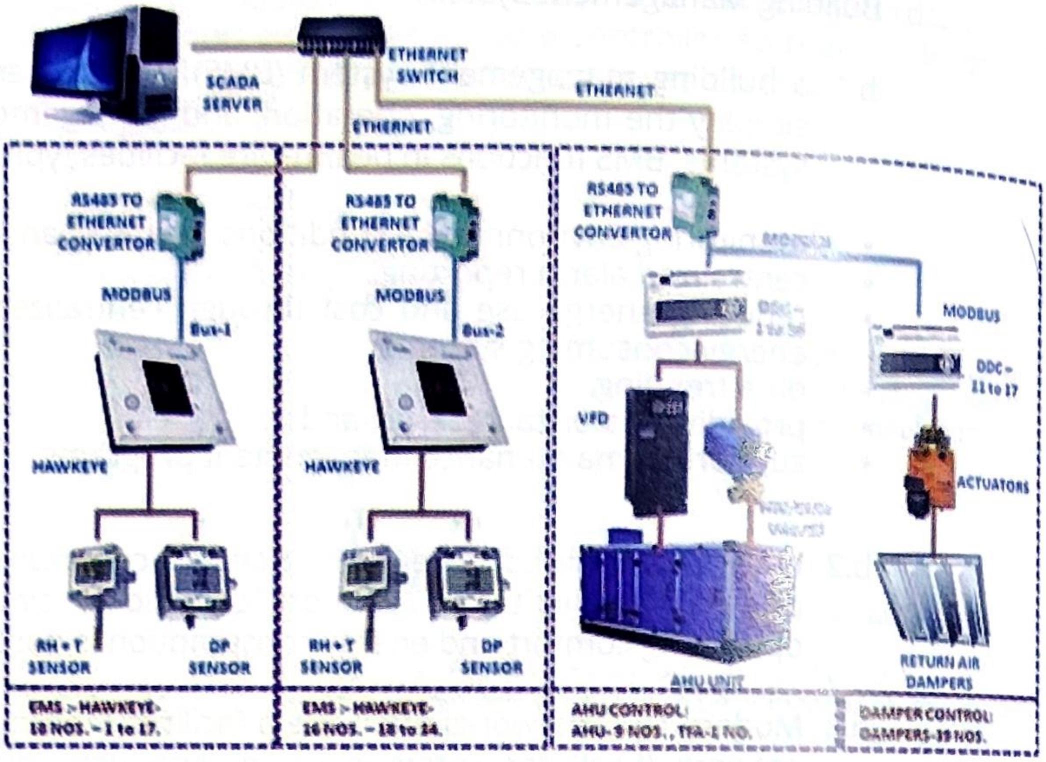

SCADA SERVER
ETHERNET SWITCH
ETHERNET
ETHERNET
RS485 TO ETHERNET CONVERTOR
MODBUS
Bus-1
HAWKEYE
RH + T SENSOR
DP SENSOR
EMS > HAWKEYE-
18 NOS. – 1 to 17.
RS485 TO ETHERNET CONVERTOR
MODBUS
Bus-2
HAWKEYE
RH + T SENSOR
DP SENSOR
EMS > HAWKEYE-
26 NOS. – 18 to 24.
RS485 TO ETHERNET CONVERTOR
DDC –
VFD
AHU UNIT
AHU CONTROL:
AHU- 9 NOS., TFA-1 NO.
MODBUS
DDC – 11 to 17
ACTUATORS
RETURN AIR DAMPERS
DAMPER CONTROL:
DAMPERS-39 NOS.

Fig. 1.4-3 Building Management System

c. Electric Control System

c.1 Electric control systems include valve and damper actuators, temperature/ pressure/humidity controllers, relays, and sensors. They are powered by low voltage or line voltage, depending on the circuit requirements. Controllers and actuators can be wired to perform in either a two-position (such as ON/OFF or limit) or proportional device. Electric controls

- are most commonly used for simple ON/OFF control;
- often use an integral sensor;
- provide a simple sequence of control;
- can function within broad environmental limits and
- are largely nonproprietary.

d. Electronic Control System

d.1 In an electronic control system, an analog sensor signal is amplified and then compared to a setpoint or override to actuate a controlled device. Electronic controls

- provide precise control;
- offer solid-state repeatability and reliability;
- allow remote sensor locations;
- allow simple remote setpoint adjustment and
- offer completely packaged actuators and controllers.

1.4.3.7 General Control Sequences

The following control sequences are used as a design guide for typically encountered hospital & health care operational situations.

1.4.3.7.1 Supply Fan Control by Duct Static Pressure/Supply Fan Motor Speed (Variable-Frequency Drive [VFD]) Control

a. The supply fan motor speed can be modulated to provide supply air system static-pressure control. During the start-up mode, the supply fan should slowly ramp up to speed to maintain the setpoint of the static-pressure controller.

1.4.3.7.2 Humidification

a. The humidifier should be modulated to maintain space or leaving room air humidity. As the room air humidity increases, the humidifier should modulate closed. The reverse should occur as the exhaust or room air humidity decreases. A high-limit, duct-mounted humidity controller should limit the signal to the humidifier if the supply air humidity exceeds 85% (hardware adjustable). On loss of airflow, the system should be driven to the closed position

1.4.3.7.3 Fire Detection and Alarm System Control

a. The control and fail-safe modes for HVAC systems with respect to fire detection and alarm system control should be carefully considered. The sequence of control is often dictated by building & fire codes; the means for the execution of the sequence, however, is left (in part) to the designer. Generally, the more control that can be left to the fire alarm system, the simpler and more reliable the system will be. In addition, the more the system is hard-wired (i.e., the less that software is used), the more reliable it will be.

1.4.3.7.4 Duct Static-Pressure Safety Control

When motorized smoke, isolation, or control dampers are used in a supply air system, the return air or exhaust air ductwork design must ensure that a closure in the supply system does not blow apart the supply ducts or collapse the return air ducts. Ductwork can be damaged if a variable-frequency drive, inlet vanes, or controls are set improperly. The following steps can prevent this situation (any delay in the smoke damper closing, however, should be approved by the authority having jurisdiction):

a. Time delay after fan(s) shut down: on a command to shut down a fan, hard-wired time-delay relays should prevent dampers from closing for several seconds after the fan(s) shut off. This should prevent a buildup of pressure until the fan spins down and prevent the fan's high-/low-static limit from tripping.

b. On shutdown, ensure that a differential pressure (DP) sensor across the fan indicates that a differential pressure of less than a preset value has been achieved before closing any damper.

c. A mechanically actuated relief damper may be placed in the ductwork to relieve excessive pressure.

d. On a signal to start the air-handling unit, the supply and exhaust isolation dampers (as well as the outdoor air damper and smoke dampers) should open before or when the fans start. Isolation damper end switches can prove that dampers are open and allow the fan(s) to start through hard-wired interlocks.

e. An analog discharge air high-static safety located before the supply air isolation/smoke damper should limit the speed of the supply fan.

f. An analog return air or exhaust air low-duct-static-pressure sensor located before each return and exhaust fan should reduce the speed of (or stop) the other fans in the system and provide input to the DDC system on sensing a static pressure below the normal operating setpoint.

1.4.3.7.5 Hydronic System Controls

The hospital Airconditioning hydronic systems should incorporate fail-safe features such as redundancy and load prioritization. The controls for such systems should include logic to address the situation when, because of failures, central system capacity is less than demand. Examples of protective measures include shutting off or reducing flow to noncritical areas, such as administration and waiting, to maintain control within more critical areas. Similar to generator load-shedding prioritization, a list of HVAC units and their priorities should be established and reviewed with the hospital administration.

1.4.3.7.6 Ultraviolet Device Controls

Any HVAC system that includes ultraviolet (UV) equipment for air treatment should include UV filters on any viewports along with door switches to disable the UV device when an access door is opened. In some cases, it will be necessary to install switches in adjacent AHU sections because UV radiation can pass through coils and filters in certain configurations.

1.4.3.7.7 Miscellaneous Control Monitoring Points

The following list of points should be considered for monitoring by the building automation system, even though they are not part of the building HVAC. In some cases, monitoring of these points and/ or systems is required by code. Through monitoring of these points, the facility operator can be alerted to problems early on, thereby minimizing service outages:

- Medical air system alarm and line pressure
- Medical vacuum system alarm and line pressure
- Medical gas system alarm and line pressure (e.g., oxygen, carbon dioxide, nitrous oxide, nitrogen, etc.)
- Domestic water booster pump alarms and line pressure
- Domestic hot-water supply and return temperature
- Fire & Jockey pump status
- Emergency generator status
- Main power circuit breaker status

1.4.3.7.8 Energy Efficiency Control Programming

The requirements of a health care setting can make it very difficult to save energy. However, there are some areas where energy efficiency can be included in the control routine. These include;

- Chilled Water Plant Manager Demand control and optimization
- supply air temperature reset for variable-air-volume systems; and
- supply air static-pressure reset for variable-air-volume systems.

1.4.3.7.9 Energy “Green” HVAC System Controls

Hospital and healthcare facilities do not often use “green” HVAC systems. When such systems are used, the control system should include sufficient y measures to avoid operational problems. Systems should include both a low-chilled water temperature limit and a space dew point monitor and limit. Failure to provide these safeties could result in condensation on surfaces. These systems also require frequent calibration of humidity sensors to ensure safe operation.

Heat recovery wheels should be monitored for differential static pressure to alert building engineers of a seal failure.

1.4.3.8 Pressurization, Outdoor Air Ventilation

1.4.3.8.1 Room Pressurization Control

Two room pressurization control methods are commonly found in hospital & health care applications: airflow differential (“cfm offset”) and room differential pressure control. It is important to keep in mind that the best method is the one that will be most reliable and require the least maintenance and calibration. With both methods of control, the difference between supply and return/exhaust air volume is made up through door undercuts and other gaps in the room structure.

Because of the complexity of both of these methods, and their tendency to lose calibration over time, it is recommended that a visual or other type of indicating system be included to provide local system status indication.

Finally, note that the current trend in rooms that include pressure controls is to dedicate them to either positive or negative function rather than make them switchable.

1.4.3.8.2 Airflow Differential Control

The pressurization required for a specific room in a hospital and healthcare facility is usually accomplished by providing differentials in the airflow rates of supply, return, and exhaust air. A room is positively pressurized if it has an excess supply air volumetric flow rate into the room compared to the sum of return and exhaust air volumetric flow rates out of the room. Negatively pressurized rooms have less supply of air than the sum of return and exhaust air. Generally, the differential is 50 to 100 cfm [24 to 47 L/s] for patient rooms and normally 5% to 10% of supply flow for larger rooms. It is very important that the differential be high enough that it can be accurately measured with typical test and balance equipment and is within the normal control and sensing range of typical DDC system sensors.

The method of flow control can vary with system design. One of the more common methods is to maintain a controlled constant supply volume via an air terminal with an airflow-measuring device and then manually set room return/exhaust (in conjunction with central return/exhaust fan volume control). Another method actively controls return/exhaust airflow from each room. This method is more expensive and less reliable because the airstream being measured is dirty; therefore, the airflow-measuring devices in the exhaust/return airstreams are prone to fouling. In general, measurement of return/exhaust air- stream flows for control purposes should be avoided unless the maintenance staff can ensure that they will be able to keep the devices in proper operating condition at all times. In most facilities, this will not be possible or practical.

The advantages of airflow differential control include immunity to room door operations (and other external influences) and simplicity of control.

1.4.3.8.3 Room Differential Pressure Control

The second common method of room pressurization control is room differential pressure. With this method, the differential pressure between a room and adjacent space such as a corridor or rooms is measured with a precision differential-pressure transducer, and the supply and/or exhaust/return airflow is adjusted to maintain a fixed setpoint.

The room differential pressure control has a more complicated control algorithm. In addition, it is subject to fluctuations from door openings and closings, exterior wind gusts, and, perhaps most importantly, changes in the room envelope, such as the wearing down of door gaskets or cracks/openings in the room structure.

1.4.3.8.4 Outdoor Air Ventilation

Outdoor air ventilation has three main functions under normal operating conditions: Providing free cooling, outdoor air ventilation, and building pressurization. The most common HVAC system ventilation includes a supply and return fan. The two most common methods of controlling the airflow are airflow matching and static-pressure control.

With airflow matching control, the supply and return airflow volumes are measured, and a fixed offset is maintained by controlling the return air fan speed. This system's setpoint is usually equal to the sum of related building exhaust volumes (e.g., toilet exhaust, electrical room exhaust) plus an offset to ensure positive building pressurization. This method works well as long as the supply and return airflow-measuring devices are accurate and low maintenance. The designer must be careful and allow sufficient ductwork to comply with the installation requirements of the airflow station. In addition, fouling of the return airflow sensor must be addressed because that air stream is usually unfiltered and laden with dirt, dust, or lint.

The mixed-air plenum is controlled to a fixed negative static pressure during minimum position operation with static-pressure control. This negative pressure is usually controlled by modulating the return air dampers. The outdoor air dampers remain in a fixed minimum position. During system calibration and start-up, the amount of outdoor air is measured by the test and balance contractor, and the static-pressure setpoint is set to the value that provides the design minimum outdoor airflow. The return fan discharge pressure is controlled to a slightly positive pressure. This ensures that air flows out of the relief dampers and into the mixed-air plenum.

The static-pressure control method has the advantages of lower maintenance and less susceptibility to dirt and poor ductwork arrangements. The static-pressure control method has the advantages of lower maintenance and less susceptibility to dirt and poor ductwork arrangements.

With static-pressure control, the mixed-air plenum is controlled to a fixed negative static pressure during minimum position (non-operation.) This negative pressure is usually controlled by modulating the return air dampers. The outdoor air dampers remain in a fixed minimum position. During system calibration and start-up, the amount of outdoor air is measured by the test and balance contractor, and the static-pressure setpoint is set to the value that provides the design minimum outdoor airflow. The return fan discharge pressure is controlled to a slightly positive pressure. This ensures that air flows out of the relief dampers and into the mixed-air plenum.

1.4.3.9 Operating Rooms, Isolation Rooms, Laboratories

1.4.3.9.1 Operating Room Controls

a. Temperature and Humidity Control

Operating rooms may require wide setpoint ranges for temperature and humidity. Codes require local room temperature setpoint adjustment throughout the entire range under all conditions. In some operating rooms, the medical staff may prefer a room temperature as low as 60°F [15.6°C]. Temperature and Humidity instruments to be monitored and controlled thru BMS with room control by-pass.

b. Variable-Air-Volume and Room Static Pressure Controls in Operating Rooms and Critical Areas

Some codes and standards require that operating rooms have constant-volume air systems. Certain codes and standards allow reduction of airflow when the operating room or critical area is unoccupied, as long as a means is provided to automatically increase airflow as soon as the room becomes occupied. Codes require, however, that room pressurization be maintained continuously. Therefore, controls should be included to ensure correct pressure relationships on air volume reset. The simplest way to do this is to have a static pressure sensor in the room to modulate the supply air volume to maintain minimum pressurization in the room, with return air volume set by a manual damper.

1.4.3.9.2 Laboratory Controls

Many hospitals and clinics have associated clinical, pathological, research, and pharmaceutical laboratories. Most hospital laboratories require constant-volume controls. If a variable- air-volume system is used, it should maintain pressure relationships between the laboratory and adjacent spaces. Care must be taken to not overcomplicate the controls in a laboratory. For example, many fume hoods and Bio Safety Cabinets available today have a bypass feature that makes them substantially constant volume. Such a hood reduces the need for a lot of special volume controls in the laboratory air-conditioning system.

1.4.4 HVAC Systems Testing Adjusting and Balancing (TAB)

1.4.4.1 The importance of testing, adjusting, and balancing (TAB) for modified and new systems before patient occupancy cannot be overemphasized. Health care facilities require validation and documentation of system performance characteristics. Combining TAB with commissioning often satisfies these requirements.

1.4.4.2. TAB is necessary to verify if the systems are performing within the design parameters and to make recommendations to optimize system performance in relation to energy consumption, occupant comfort, and infection control.

1.4.4.2. Effective and efficient TAB requires systematic, thoroughly planned procedures implemented by competent, qualified, and certified independent TAB agencies.

1.4.4.2 TAB procedures and activities shall cover air and hydronic systems and include laboratory fume hoods and biosafety cabinets.

1.4.4.3 It is recommended that periodic TAB audits on the air systems be conducted with a minimum frequency of five (5) years for existing facilities. Essential

1.4.4.5 TAB procedures, instruments, documents, and forms shall be in accordance with any one of the following guidelines:

a. ASHRAE Standard 111-2008 Testing, Adjusting, and Balancing of HVAC Systems for Buildings (ANSI Approved)

b. NEBB Procedural Standard for Testing, Adjusting, and Balancing of Environmental Systems, Ninth Edition, 2019

c. NEBB Procedural Standard for Certified Testing of Cleanrooms, Third Edition, 2009

d. AABC National Standards for Total System Balance, Seventh Edition

e. NEBB Procedural Standard for Fume Hood Performance Testing, Second Edition

1.4.5 HVAC Systems Operations and Maintenance

1.4.5.1 As it was theorized that building construction costs represents only 11% of total building costs over 40 years and that operations, on the other hand, make up 50% (Harteen, et al. 2000), improper facility operation and maintenance can mean wasted and unnecessary expenditures on equipment replacement costs. It can also cause random disruptions due to mechanical system and equipment failure, which is unacceptable in healthcare facilities. Furthermore, systems may be forced to perform outside their optimum operating parameters, resulting in higher energy costs and failure to provide the necessary environment for patient treatment and healing.

A good maintenance and operating program must be established and implemented to ensure that the healthcare facility's systems operate reliably to provide its essential objectives of providing effective indoor air quality, minimizing the risks of propagation of pathogens, keeping the indoor environment suitable for patient care while operating within reasonable consumption of energy.

1.4.5.2 It is recommended that operations and maintenance programs be premised on either the Predictive maintenance approach or the Proactive maintenance approach. The basic principle of both promotes checking the conditions of equipment as it operates with the time interval principle as a complementing parameter for determining equipment replacement cycles. The proactive approach adds the root cause analysis principle in the program. Critical items for root cause analysis may include the following:

a. Vibrational Analysis
b. Infrared Thermographic Inspection
c. Motor Current Analysis
d. Oil Analysis
e. Refrigerant Analysis
f. Shaft Alignment
g. Dynamic Balancing
h. Control sensor calibration

1.4.5.3. A consistent practice of inspecting and maintaining HVAC systems shall enumerated in operations and maintenance plans. ANSI/ASHRAE/ACCA Standard 180-2018 Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems may be referred to.

1.4.5.3 ASHRAE 170-2013 offers recommended operations and maintenance procedures for certain healthcare-specific rooms:

a. For Operating Rooms

   a1. Each operating room shall be tested for positive pressure semi-annually or on an effective preventive maintenance schedule.

   a2. When HEPA filters are present within the diffusers of the operating room, the filter should be replaced based on pressure drop.

   a3. Operating and cesarean delivery rooms ventilation system shall operate at all times, except during maintenance and conditions requiring shutdown by the building's fire alarm system.

b. Protective Environment (PE) Rooms shall remain under positive pressure with respect to all adjoining rooms, especially whenever an immunocompromised patient is present, and they should be tested for positive pressure daily. HEPA filters shall be replaced based on pressure drop.

c. Airborne Infection Isolation (AII) Rooms shall remain under negative pressure especially whenever an infectious patient is present. They shall be tested for negative pressure daily whenever an infectious patient is present.

1.4.5.4 Air distribution systems: Ductwork collects dust deposits and becomes contaminated with microbial colonization. Excessive dust build-up in ducts can also result in significantly reduced air system performance. Cleaning processes require access to the interior of the ductwork and involve placing the duct under a vacuum in combination with mechanical or power brushing. In addition, microbial biocides and sealants may be applied to the inside surfaces to prevent fungal growth and prevent the release of particulate matter.

a. While standard procedures place the duct being cleaned under negative pressure during the procedure, the surrounding area may be contaminated if the negative pressure is carelessly maintained and if not provide adequate time for disinfecting or encapsulant chemicals to dry. Chemical applications, when improperly mixed or applied, may result in occupant complaints of irritation and adverse health effects. For these reasons, duct cleaning activities should be carefully coordinated beforehand with the hospital staff the procedures should be carried out only by properly trained and qualified personnel and all necessary containment and protective measures should be adhered to.

b. The upstream and downstream faces of the cooling coils must be accessible to the maintenance worker using a power washer.

1.4.5.5. Emergency operations during epidemics and pandemics shall include

1.4.6 HVAC Systems Commissioning

1.4.6.1 Commissioning is a quality assurance and quality control process that provides the essential documentation, testing, and training to ensure that a system meets both its design intent and operational needs. The process includes preparing the facility's staff to operate systems and ensuring, through documented verification, that all HVAC systems perform individually and interactively according to documented design intent and the healthcare facility's operational needs. Commissioning is most valuable when system performance is evaluated under a full range of load and climatic conditions. Assessing system performance under part-load or extreme conditions is often the best way to discover problems in buildings and correct them before occupancy.

1.4.6.2 The Commissioning Authority (CxA) is the person or entity that leads the commissioning process. A CxA with broad experience with building systems is recommended as the responsible party to guide the commissioning process. The CxA shall report directly to the facility owner.

1.4.6.3 The commissioning focuses on documented conformation that a facility fulfills the specified performance requirements of the healthcare owners, personnel, and patients. Commissioning is intended to achieve the following objectives:

a. Ensure equipment and systems are properly installed and receive adequate operational checkout by installation contractors.

b. Verify and document the proper operation and performance of equipment and systems.

c. Ensure that the design intent and owner's requirements for the project are met.

d. Ensure that the project is thoroughly documented.

e. Ensure that the facility operating staff is adequately trained.

1.4.6.4 The commissioning authority must ensure that the design team takes explicit responsibility for documenting the following items:

a. Design Criteria: Thermal Conditions, Humidity, Occupancy (hours and levels of activity), Plug Loads, Special Loads, Air quality design criteria, Pressurization and infiltration requirements, Total and outside air requirements, Energy efficiency, Maintainability

b. Functional Performance Test Specifications:

b1. Description of the equipment and systems to be tested including types, components, sub-assemblies, intended operation, capacity, temperature control, and sequences of operation.

b2. Identification of functions to be tested, including operational and performance data that should address seasonal changeovers, part-load strategies, design setpoints of the control systems, and range of permissible adjustments. Other items to be considered include life safety modes of operation and any applicable energy conservation procedures.

b3. Defining the conditions under which the test is to be performed., considering all possible operating modes, such as full and partial loads and extremes of operating temperatures and pressures.

b4. Specification of acceptance criteria in clear terms. The acceptance criteria shall be quantitative, and the accuracy required should be consistent with the equipment and system design limitations.

1.4.6.5 Narrative discussions on the commissioning authority qualifications, commissioning processes, functional performance tests, and other detailed scope of commissioning objectives can be found in the following references:

a. ASHRAE Guideline 0-2019 The Commissioning Process

b. ASHRAE Standard 202-2018 Commissioning Process for Buildings and Systems

c. ANSI/NEBB Standard S110-2019, Second Edition Whole Building Technical Commissioning of New Construction

d. ANSI/NEBB Standard S110-2019, Third Edition Technical Retro-Commissioning of Existing Buildings

1.5 CLINICS AND OUTPATIENT FACILITIES

1.5.1 Occupancy Classifications

1.5.1.1 An outpatient clinic may be a free-standing unit, part of an acute care facility, or part of a medical office building. Any outpatient surgery is performed without anticipation of the overnight stay of patients.

1.5.1.2 When specific treatments in the outpatient facilities are medically consistent with hospital-based treatments, then environmental design guidance for hospitals should also apply to the outpatient treatment location. Outpatient and clinic facilities shall be designed based on the criteria in Section 1.3 of these Guidelines.

1.5.2 Diagnostic or Treatment Clinics

1.5.2.1 A diagnostic clinic is a facility where ambulatory patients are regularly seen for diagnostic services and minor treatment but where major treatment requiring general anesthesia and surgery is not performed.

1.5.2.2 The design criteria for outpatient diagnostic and treatment clinics include Infection sources and control measures, air quality, air movement, temperature, and humidity.

1.5.2.3 Outpatient clinics may include the following:

a. Ambulatory Surgery: This facility is generally Class A, which provides minor surgical procedures under topical local or regional anesthesia without preoperative sedation. These facilities will, however, require the following support spaces:
- Substerile area: Negative pressure; provide an exhaust grille directly above the sterilizer door.
- Scrub area: Part of the sterile zone
- Clean workroom: This area needs positive pressure relative to the corridor and the soiled workroom.

- Soiled workroom: This area needs negative pressure relative to all the other spaces.

b. Freestanding Emergency Facility (Urgent Care): A freestanding emergency facility offers a variety of health care services to patients independently of a hospital. Such a facility shall be held to the same standard as a hospital emergency department. All spaces for patient care should maintain equivalent infection controls and comfort control of temperature and humidity.

c. Freestanding Birthing Center: Freestanding birthing centers are facilities that provide labor, delivery, recovery, and possibly postpartum services. It usually contains at least one delivery room for emergency cesarean sections. This room shall be identical to a hospital delivery room and provide complete inhalation anesthetics.

d. Cancer Centers: These facilities shall be designed to hospital ventilation standards and contain most oncology services provided in inpatient facilities, such as chemotherapy, radiation treatments, CT and MRI, nuclear medicine, mammography, and ultrasound, as well as exam rooms, pharmacy, and laboratories. Equipment heat gains stringent environmental requirements influence very sophisticated ventilation and air cooling processes.

e. Dialysis Centers: All the dialysis stations shall be exhausted. Air from the nursing station and other clean support spaces can be recirculated, but most of the treatment space shall be exhausted. These centers may also have infectious dialysis rooms that require separate exhaust systems.

f. Exam Clinics/Rooms: These spaces are often used in outpatient settings. They involve all type of medical services that may include local anesthesia. Exam rooms shall have ducted returns and ventilation based on hospital standards.

g. Laboratory: Laboratories in outpatient clinics shall follow the same rules as the ventilation criteria in Section 1.3 of these guidelines.

h. Pharmacy: The pharmacy in an outpatient setting can be ventilated as retail. If any specialty preparations are to be made, such as for chemotherapy or nuclear medicine, hospital pharmacy design rules shall apply. Fume hoods require attention both to exhaust and room diffusion.

i. X-Ray Room: It is encouraged that there should be as much information as possible about the X-ray equipment to determine heat gains and environmental requirements.

j. MRI: Similar to MRI suites in hospitals, the MRI equipment manufacturer determines the temperature and humidity requirements. Extensive electronics will require that computer room air conditioning units serve the space. Adding a chilled water coil to a DX unit builds in redundancy. All electrical and mechanical penetrations of the shielding grid must have a dielectric connection for piping and flexible fabric connections for ductwork. Air devices within the space must be nonmagnetic, usually stainless steel or aluminum.

k. Ophthalmology and Optometry: These spaces in the outpatient setting do not require special requirements other than the required ventilation and filtration specified in Section 1.3 of this Guidelines and low-velocity air distribution in the exam room.

l. Endoscopy: The endoscopy suite shall have negative pressure relative to all surrounding spaces and air shall be exhausted to the outside. The air supply in this room shall be 6-10 air changes per hour. Conventional overhead air distribution shall be used. The air supply shall be located directly over the procedure table and the exhaust inlets at the perimeter. Exhausting air to the general exhaust system is allowed.

m. Bronchoscopy: The bronchoscopy room shall be treated as an airborne infection isolation (AII) room with the room pressure negative and the air exhausted completely.

n. Cardiac Catheterization and Angiography: These rooms are equipment-intensive. The equipment manufacturer shall determine the environmental requirements. Treatment rooms shall have low sidewall returns and low-velocity, non-aspirating ceiling supply diffusers over the tables. The equipment room is best served by a process air cooler. The control and treatment rooms require close control of temperature and humidity.

1.5.3 Dental Care Facilities

1.5.3.1 Dental facilities require more comprehensive ventilation because of the work performed in such facilities. Bioaerosols and particulates are produced by a wide range of dental procedures. Teeth cleaning, scaling, and drilling can produce small particulates at less than 5 microns. The use of nitrous oxide as an analgesic is also a concern because NO_2 is heavier than air and may cause asphyxiation. Ventilation is also an important measure to mitigate the risk of transmission of airborne pathogens.

1.5.3.2 The ventilation requirements for the different areas in a typical dental facility are as follows:

Table 1.5-1 Design Criteria for Ventilation Systems for Various Areas in a Dental Facility

Based on ASHRAE Journal 1998 Dental Ventilation Theory and Applications (Ninomura and Byrns)

Space	Total ACH	Outdoor Air ACH	Space Pressure	Filtration
Dental Operatory	10	2	N	MERV-14
Clean Up Alcove	10	2	N	MERV-14
Laboratory Room	6	2	N	MERV-14
Darkroom	10	2	N	MERV-14
Orthodontic X-ray	2	2	Variable	MERV-14
General/Prophylaxis	6	2	N	MERV-14
Reception	2	2	Variable	MERV-14
Laboratory	12	3	N	MERV-11
Oral Surgery	12	3	P	MERV-14
Periodontic	12	3	P	MERV-14
X-ray Film Processing	10	3	N	MERV-10
Dental X-ray	6	2	P	MERV-10

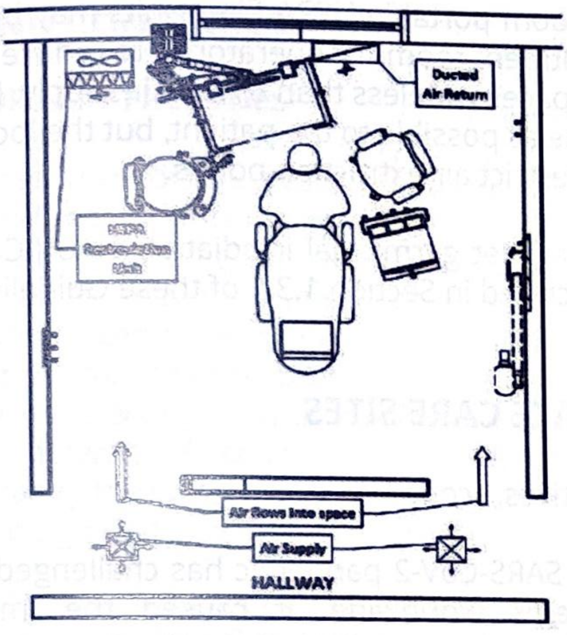
1.5.3.3 There are design considerations that may be applied especially for reducing airborne infectious aerosol exposure.

1.5.3.3.1 Patient Placement Strategies

a. For multiple chair areas, there should be at least 2 meters (6.5 feet) distance between chairs.

b. Place physical barriers between patient chairs with floor-to-ceiling coverage preferred.

c. Patients should be oriented with their head away from pedestrian corridors, towards the rear walls, and near the return air vents.


Ducted Air Return
HEPA Recirculation Unit
Air flows into space
Air Supply
HALLWAY

Graphic by CDC/NIOSH

Fig. 1.5-1 Recommended Patient Placement
ASHRAE Technical Resources for Dental Facilities

1.5.3.3.2 Primary source management to limit contamination at the source. Source Control in Dentistry seeks to remove the airborne particles before they can travel beyond the patient. The mechanical suction evacuation of aerosols exhaled from the patient helps to minimize their distribution and mixing within the room. The exhaust air shall pass through MERV-14 filter or its equivalent before it is discharged outside.

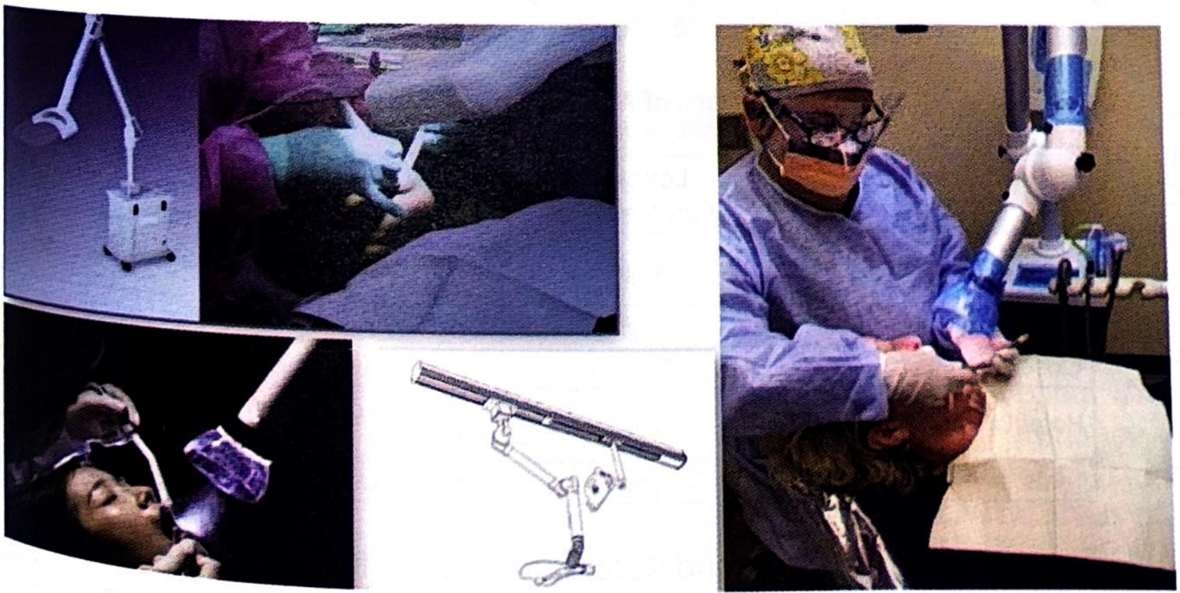


Fig. 1.5-2 Contamination source control and management
Lifted from the ASHRAE Technical Sources for Dental Facilities

1.5.3.3.3 In-room portable HEPA filter units may be utilized inside dental treatment rooms or operatories to reduce bioaerosols, especially in spaces with less than 6 ACH air supply. Place the air cleaner as close as possible to the patient, but the location shall not impede or restrict air extraction points.

1.5.3.3.4 Ultraviolet germicidal irradiation or UV-C may be employed, as described in Section 1.3.5 of these Guidelines.

1.6 ALTERNATE CARE SITES

1.6.1 Objectives, scope

1.6.1.1 The SARS-CoV-2 pandemic has challenged almost all healthcare systems worldwide. It caused the immediate design and construction of alternate care sites to relieve the strain on healthcare systems.

1.6.1.2 Alternate Case Sites (ACS) are temporary facilities with the flexibility to provide spaces for patient care to limit the overload of hospital occupancy and other urgent health care facilities during epidemics or pandemics and allow treatment of severely ill patients. This guide will be applicable to large spaces like arenas, convention centers, and school gymnasiums. Other feasible alternate sites like hotels, dormitories, barracks, and tent alternate sites may find the applicability of this guideline to a lesser degree. The types of ACS facilities and their levels of applicability are shown in the table below:

Table 1.6-1 Types of Alternate Care Sites
Alternate Care Site HVAC Guidebook 2020, ASHRAE and the U.S. Army Corp of Engineers

Temporary Facility Type	Level Of Applicability	Comments
Arenas, Convention Centers	High	Flexible location with outdoor buffer zones
High School Gymnasium	High	Flexible location with smaller bed capacity
Closed Hospitals	Medium	Infrastructure may need modifications
Hotel/Barracks/Dormitory	Low	Non-acute patient only to minimize disruption of host site
Tents	Low	Limited use due to climatic conditions

1.6.2 Requirements and Recommendations for Mechanical Systems

1.6.3 Approaches for supply and exhaust air flow

1.6.4 Environmental Space Conditions

1.7 PLANNING AND CONSTRUCTION

1.7.1 PLANNING FOR NEW FACILITIES

1.7.1.1 Advances in medicine, evolving medical technology, the discovery of new diseases, and the emergence of new contaminants, either benign or pathogenic, dictate the need for a constant reevaluation of the air conditioning needs of a healthcare facility. While air conditioning can support the treatment and healing of patients, and ventilation can provide protection against airborne infection and minimize nosocomial cases, it has and will always be a challenge to balance between life safety and the costs of the system, and the cost of operating the system. The following is a suggested prioritization of HVAC design system characteristics (Turpin 2013):

1. Performance (infection control, comfort, patient outcome)
2. Safety (life safety, fire, potential injuries)
3. Reliability
4. Maintenance cost
5. Energy cost
6. Adaptability

Healthcare facilities are energy-demanding and energy-dependent. Furthermore, healthcare facilities pose challenges not usually encountered in commercial and comfort cooling applications: a) need to restrict movement in and between departments, b) specific requirements for ventilation and filtration to dilute and remove contamination, c) different temperature and relative humidity requirements for different areas, d) design sophistication required for the accurate control of environmental conditions.

1.7.1.2 Zoning, or using separate air systems for different departments, is recommended to a) compensate for exposures caused by orientation or for other conditions imposed by specific building configurations, b) minimize recirculation between departments, c) simplify provisions for operation on emergency power, d) energy conservation.

1.7.1.3 Ducting the air supply from several air handling units into a manifold will give central systems standby capacity. This is essential if the air supply is not to be interrupted by routine maintenance or component failure. Separating supply, return, and exhaust systems by department is desirable. The desired balance in critical areas may be achieved by interlocking the supply and exhaust air systems. The exhaust fan shall stop its operation when supply fans are stopped in areas where positive pressure is to be maintained relative to adjacent spaces. Similarly, the supply air flow shall cease operation when the exhaust fan is deactivated in areas maintained at negative pressure.

1.7.1.4 When planning HVAC systems for new facilities, the design documents shall meet the following requirements:

1.7.1.4.1 General Mechanical and Electrical Equipment Rooms: Access to mechanical rooms shall be planned to avoid intrusion of maintenance personnel into surgical and critical care areas. Mechanical rooms that are accessible to the outside provide ease for the replacement of equipment and components.

1.7.1.4.2 Mechanical Room Layout: Mechanical room layout shall include sufficient space for access to equipment for operation, maintenance, and replacement. Catwalks and ladders shall be provided for access to equipment that cannot be reached from the floor. Floors in mechanical rooms shall be sealed, including component penetrations, especially when such rooms are above surgical suites and critical care areas.

1.7.1.4.3 Maintenance/Repair Personnel Access: Safe and practical means of personnel access should be provided. A minimum of 600 mm (2 feet) of clearance shall be required at all service points to mechanical equipment to allow personnel access and working space. During plan review, serviceability requirements for mechanical equipment rooms, corridors, occupied spaces, behind walls, above ceiling, and/or buried in the ground should be verified.

1.7.2 PLANNING FOR EXISTING FACILITIES

1.7.2.1 Many hospitals, after a significant number of years and numerous remodeling, upgrading, and additions, encounter typical conditions and issues such as:

- Air filtration may not be up to current standards.
- Older equipment may not have the capacity to meet new cooling loads or they may be at the end of their life cycle.
- Controls may be in need of an upgrade.
- Ductwork may be dirty, especially return and exhaust ducts.
- Hydronic systems may exhibit deterioration of piping.
- Systems may not be appropriate for evolving functions and technology.
- There may be a lack of balancing capability, resulting in improper air and water flow.
- Systems are in need of retro-commissioning, or they may not

have been performed from the initial start-up.

- Central chiller plants may contain CFCs, or they may need to be upgraded due to the age of equipment, lack of flexibility, or capacity.
- Horizontal or vertical space for distribution may not be available to permit new additions of new systems or elements.
- Systems may be energy-intensive.
- There may be a lack of sufficient clearance for adequate maintenance.
- There may be significant maintenance programs that have been deferred.

1.7.2.2 Any HVAC system and infrastructure will have both limitations and capabilities that will influence planning for existing facilities. A comprehensive evaluation plan that will assess an existing facility's utilities, architecture, and engineering infrastructure should be surveyed and evaluated to correct deficiencies. Guidance to planning for existing facilities may be found in:

a. Chapter 6 of the 2003 ASHRAE HVAC Design Manual for Hospitals and Clinics

b. Section 8 of the ANSI/ASHRAE/ASHE 170-2013 Ventilation of Health Care Facilities

1.7.2.3 Renovations will often require changes or disruption to existing systems. Continuity of service to areas served systems that will not be changed should be considered.

1.7.3 CONSTRUCTION, RENOVATION, REPAIR, DEMOLITION

1.7.3.1 Construction and renovations will cause environmental disturbances in healthcare facilities, and it shall be expected that airborne contaminant levels will increase. Special attention to infection control should be required.

1.7.3.2 *The AIA Guidelines for Design and Construction of Hospitals and Health Care Facilities* states that "design and planning for projects shall require consultation from infection control and safety personnel. This consultation is termed as "infection control risk assessment" (ICRA). The consultative team may be a multi-disciplinary team with members as recommended in *Box 4 of the 2003 CDC Guidelines for Environmental Infection Control in Health-Care Facilities*

1.7.3.3. Strategies and guidelines for managing construction and renovation to reduce risks can be found in the following:

a. 2003 ASHRAE HVAC Design Manual for Hospitals and Clinics.

b. 2003 CDC Guidelines for Environmental Infection Control in Health-Care Facilities.

1.7.4 DISASTER MANAGEMENT

1.7.4.1 Healthcare facilities are subject to external and internal disasters that affect HVAC systems that, in effect, will disrupt services. Internal disasters affect the hospital itself, its patients, its personnel, or its spaces (fire, power and/or water disruption, failure or breakdown of systems, building failures). External disasters like natural disasters or man-made accidents and emergencies that affect communities in which the hospital is integrated (trauma, biological, chemical, nuclear, evacuation)

1.7.4.2 Essential services in emergencies and disasters shall include power, water, ventilation, sterilization, communication, and transportation.

1.7.4.2 Disaster management would require identifying mechanical services and spaces required for disaster situations. General principles and strategies for disaster management and a checklist of recommended mechanical services can be found in Appendix B of the 2003 ASHRAE HVAC Design Manual for Hospitals and Clinics.

1.8 REFERENCES:

ANSI/ASHRAE/ASHE Standard 170-2013 Ventilation for Health Care Facilities

ANSI/ASHRAE/ASHE Standard 170-2017 Ventilation for Health Care Facilities

ASHRAE HVAC Design Manual for Hospitals and Clinics

ANSI/ASHRAE 52.2-2017 Standard Method for Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

ANSI/ASHRAE 62.1-2019 Standard Ventilation for Acceptable Indoor Air Quality

2003 CDC Guidelines for Environmental Infection Control for Health-Care Facilities

2001 Edition AIA Guidelines for Design and Construction of Hospital and Health Care Facilities

21st Edition of ACGIH Industrial Ventilation

ASHRAE 2019 Handbook of Applications

ASHRAE 2017 Handbook of Fundamentals

ANSI/ASHRAE Standard 55-2013 Thermal Environmental Conditions for Human Occupancy

ASHRAE Indoor Air Quality Guide

Alternate Care Site HVAC Handbook 2020 (ASHRAE and the US Army Corp of Engineers)

Dental Ventilation Theory and Application; Paul T. Ninomura, George Byrns (ASHRAE Journal February 1998)

Ventilation Information for Dentistry 2020, NHS Education for Scotland

CHAPTER 2: FIRE PROTECTION AND LIFE SAFETY

2.1 GENERAL

Fire and smoke are a big concern for hospitals since most occupants cannot **self-preservation.** Most of them need assistance from staff. If not adequately protected, a building can put patients at risk because smoke and fire can travel thru openings in buildings. To facilitate evacuation, the effects of fire and smoke can be contained when fire compartments separate sections of buildings. If designed and maintained properly, fire compartments can contain the fire in the room of origin. **Early detection** of fire thru manual and automatic fire and smoke detectors can help in evacuating affected fire compartments and control fire by manual fire-fighting (fire extinguishers & fire hose cabinets) and compartmentation. An automatic **fire suppression** system like sprinkler can also control fire if manual fire-fighting cannot be done. Interior finishes and other construction materials should also be non-combustible to minimize the fuel load in the building.

Hospitals can be constructed of non-combustible or fire-resistive materials, but hospitals also house considerable fire hazards like the following:

1. Significant amount of bed linens.
2. There are laboratories and operating rooms where considerable amounts of flammable liquids and or gases can be used.
3. Presence of oxygen bottles or oxygen transport system.

Fire suppression and compartmentation can reduce the risks from the abovementioned conditions.

Fire Protection and Life Safety Concept. All hospitals shall be designed, constructed, maintained, and operated to minimize the possibility of a fire emergency requiring the evacuation of occupants. Because the safety of health care occupants cannot be ensured adequately by dependence on evacuation of the building, their protection from fire shall be provided by appropriate arrangement of facilities; adequate, trained staff; and development of operating and maintenance procedures composed of the following:

1. Design, construction, and compartmentation.
2. Provision for detection, alarm, and extinguishment.
3. Fire prevention procedures and planning, training, and drilling programs for the isolation of fire, transfer of occupants to areas of refuge, or evacuation of the building

2.2 SERVICES OF CERTIFIED FIRE PROTECTION SPECIALIST

Projects involving the design or modification of hospitals shall require the services of Certified Fire Protection Specialists. He or She shall be an integral part of the design team and must be involved in every aspect of the design, construction and commissioning related to life safety and fire protection. They shall be engaged at the beginning with the initial conceptual design. The scope of work shall include but is not limited to, building code analysis, life safety code analysis, design of fire suppression systems, water supply analysis, and a multi-discipline review of the entire project related to fire protection and life safety.

2.3 FIRE SAFETY COMPLIANCE REPORT (FSCR)

Planning for the construction of hospitals shall include the preparation of a Fire Safety Compliance Report. It shall be done based on the requirements of the Fire Code of the Philippines, National Building Code, and Life safety Code or NFPA 101. The report shall identify the proposed Hospital's required fire protection, detection and life safety requirement. The Certified Fire Protection Specialist or a Fire Safety Practitioner shall prepare the Fire Safety Compliance Report to identify the required fire protection and life safety requirements of the hospital, and the respective discipline involved in the design (architectural and engineering) shall confirm the inclusions of the requirements for fire protection and life safety.

2.4 BUILDING CONSTRUCTION

2.4.1 Minimum Construction Requirement

The Fire Code of the Philippines of 2019 contains the full requirement for the minimum construction requirement. The most significant requirement is outlined in this guideline as follows:

1. Healthcare buildings of one (1) storey only may be constructed of protected non-combustible construction, fire-resistive construction, protected ordinary construction, protected wood frame construction, heavy timber construction or unprotected noncombustible construction.
2. Healthcare buildings two (2) storeys or more shall be at least of **fire-resistive construction**.
3. Healthcare occupancies of two (2) or more storeys shall have enclosure walls of non-combustible materials having a fire-resistance rating of at least two (2) hours around stairways, elevators, chutes, and other vertical openings between floors.
4. All **interior walls and partitions** in buildings of fire-resistive and non-combustible construction shall be composed of non-combustible materials.
5. Every healthcare sleeping room shall have an outside window or outside door arranged. and located so that it can be opened from the inside without the use of tools or keys to permit the products of combustion and to allow any occupant to have direct access to fresh air in case of emergency.

2.5 COMPARTMENTATION/SUBDIVISION OF BUILDING SPACES

Compartmentation provides a refuge area for the occupants of hospitals. If one compartment is involved in a fire and requires evacuation or relocation, the second compartment can serve as a refuge area for horizontal relocation, of the occupants. Two basic evacuation strategies are total evacuation and horizontal relocation (also described as defend-in-place). Determining which strategy is more appropriate depends on a variety of factors, including types of incidents anticipated to occur, expected movement(s) of occupants during the incident, physical or cognitive evacuation capabilities of the occupants, facility configuration, and fire protection and life safety features in place.

2.5.1 **Total Evacuation.** Upon notification of an emergency, a facility incorporating "total evacuation" requires all occupants to exit the facility completely without assistance. This can only be done if occupants can evacuate without assistance and the building is a single-storey building.

2.5.2 **Defend In Place.** A facility incorporating "defend-in-place" requires trained facility staff to assist occupants in relocating to a predetermined safe location on the same floor upon notification of an emergency. It is not practical or reasonable to expect inpatients on upper floors to participate in a total evacuation. Safe locations are created by subdividing each floor into two or more fire/smoke compartments, where horizontal and vertical construction elements have been incorporated to limit the transfer of fire and smoke. To maximize the "defend-in-place" concept for evacuation, horizontal exits shall be utilized to the fullest extent possible. The "defend-in-place" and the use of horizontal exits are stated in our fire Code. The defend-in-place will require fire compartments starting from the rooms to corridors, subdivision of each floor, and vertical subdivision of the buildings into floors. In addition to this, other types of occupancies and -hazard facilities shall also be separated from the hospital by fire-resistance construction.

The first level of defense is the room enclosure. Rooms shall be at least one-hour fire-rated with fire doors, door closers, windows, automatic fire detection, and fire suppression systems. Patients, with or without the help of hospital personnel, can leave the room immediately upon detection of fire. The fire-rated enclosure of the room will help contain the fire in the room of origin and resist the spread of fire in adjacent areas. Detection of fire through an automatic fire detection system can alert hospital personnel to make the necessary action, like assisting the patient to leave the room, conducting manual fire-fighting, opening the window for venting smoke, and alerting the building fire brigade in the building. In case manual fire-fighting is not possible, the sprinkler system will act as the second line of defense for the building.

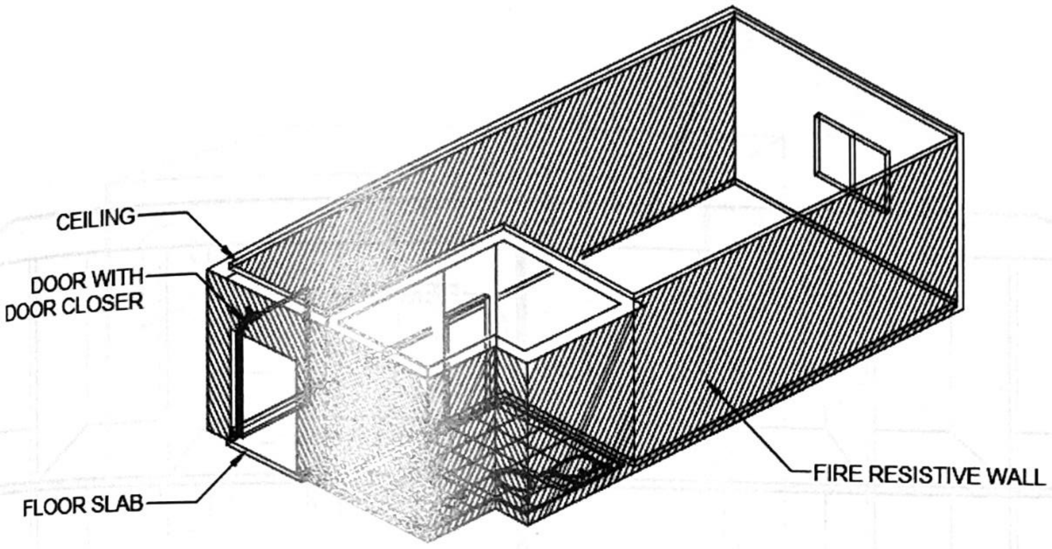

CEILING
DOOR WITH DOOR CLOSER
FLOOR SLAB
FIRE RESISTIVE WALL

Figure 3.1 Fire Rated Enclosure For Rooms

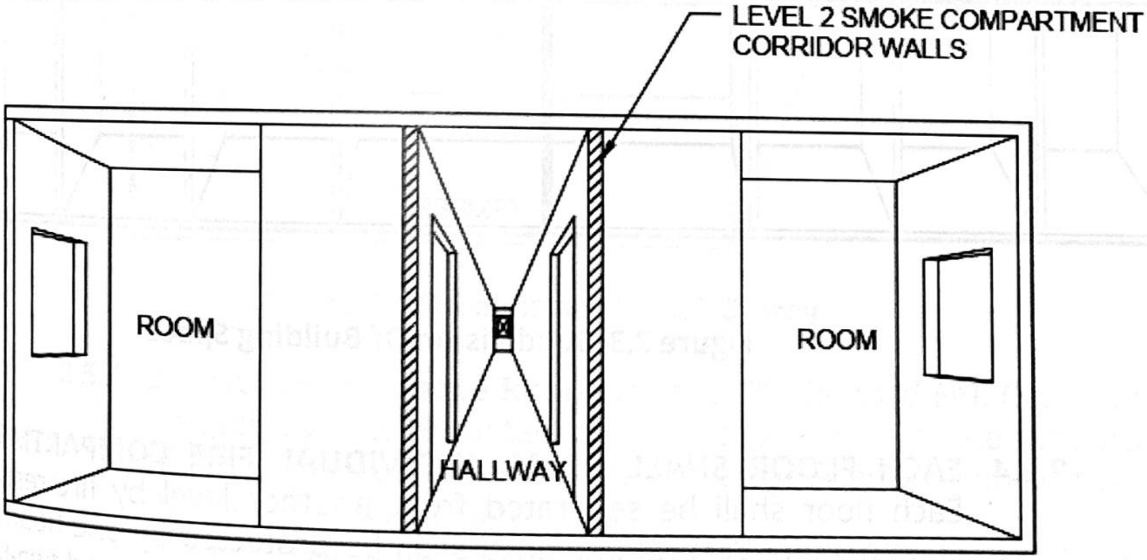

LEVEL 2 SMOKE COMPARTMENT CORRIDOR WALLS
ROOM
HALLWAY
ROOM

Figure 3.2 Fire Rated Enclosure For Corridor
Smoke Compartment/Subdivision of Space

2.5.3 SUBDIVISION OF BUILDING SPACE. The life safety concept for multi-level hospitals is to defend-in-place. It will be difficult to evacuate patients who are incapable of self-preservation, so each hospital floor should be subdivided into a minimum of two fire compartments. In case of fire in one compartment, the other compartment can serve as an area of refuge while fire-fighting is conducted in the first compartment.

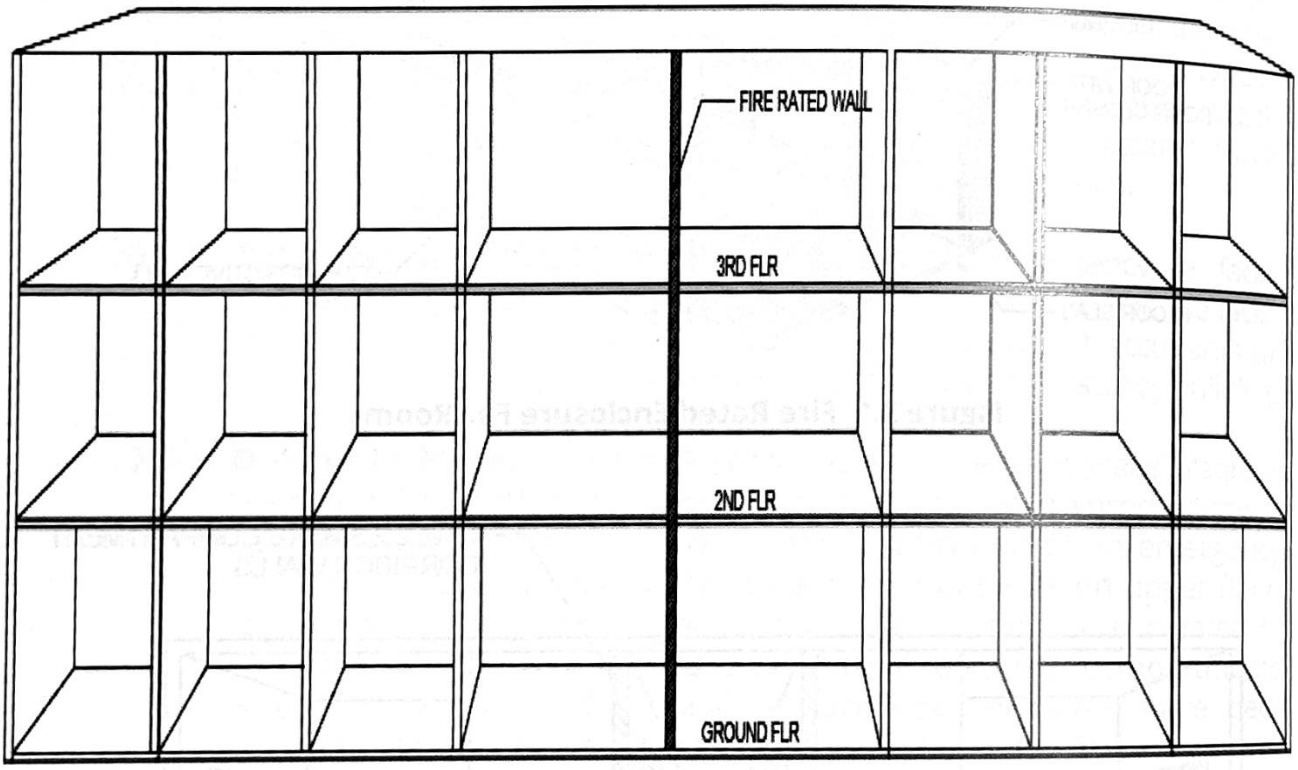


Figure 3.3 Subdivision Of Building Space

2.5.4 EACH FLOOR SHALL BE AN INDIVIDUAL FIRE COMPARTMENT.

Each floor shall be separated from another level by fire-resistive construction. Vertical openings shall be protected by one-hour fire-resistive construction if connecting three levels or less and two-hour fire-resistive construction for four levels or more. Openings in this fire resistive construction shall be fire-rated.

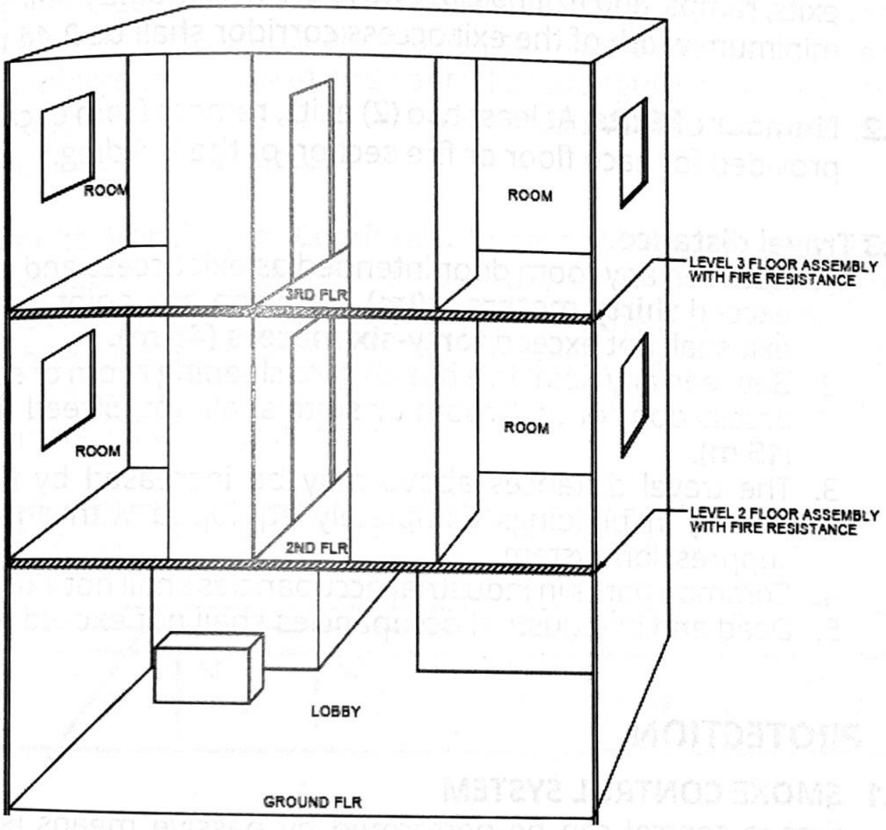

ROOM
ROOM
3RD FLR
LEVEL 3 FLOOR ASSEMBLY WITH FIRE RESISTANCE
ROOM
ROOM
2ND FLR
LEVEL 2 FLOOR ASSEMBLY WITH FIRE RESISTANCE
LOBBY
GROUND FLR

Figure 3.4 Subdivision Of Each Storey

2.5.5 Subdivision of Space Requirement. The Revised Fire Code of the Philippines of 2019 contains the full requirement for the subdivision of the space requirement. The most significant requirements are outlined in this guideline as follows:

Smoke partitions shall be provided, regardless of building construction type, as follows:

1. To divide into at least two (2) compartments every storey used by inpatients for sleeping or treatment and any storey having an occupant load of fifty (50) or more persons.
2. To limit on any storey the maximum area of each smoke compartment to no more than two thousand one hundred square meters (2,100 square meters), of which both length and width shall be no more than forty-six meters (46 m).
3. At least two and eight tenths square meters (2.8 square meters) per occupant for the total of bed or per patient shall be provided on each side of the smoke partition's corridor.

2.6 DESIGN OF EGRESS SYSTEM

2.6.1 Means of Egress Components. Doors, stairs, corridors, horizontal exits, ramps, and exit passageways are acceptable means of egress. The minimum width of the exit access corridor shall be **2.44 meters.**

2.6.2 Number of Exits. At least two (2) exits, remote from each other, shall be provided for each floor or fire section of the building.

2.6.3 Travel distance.

1. Between any room door intended as exit access and an exit shall not exceed **thirty meters (30m).** Between any point in a room and an exit shall not exceed **forty-six meters (46 m).**
2. Between any point in a health care sleeping room or suite and an exit access door of that room or suite shall not exceed **fifteen meters (15 m).**
3. The travel distances above may be increased by **fifteen meters (15 m)** in buildings completely equipped with an automatic fire suppression system.
4. Common paths in industrial occupancies shall not exceed **10 meters.**
5. Dead end in industrial occupancies shall not exceed **6 meters.**

2.7 PROTECTION

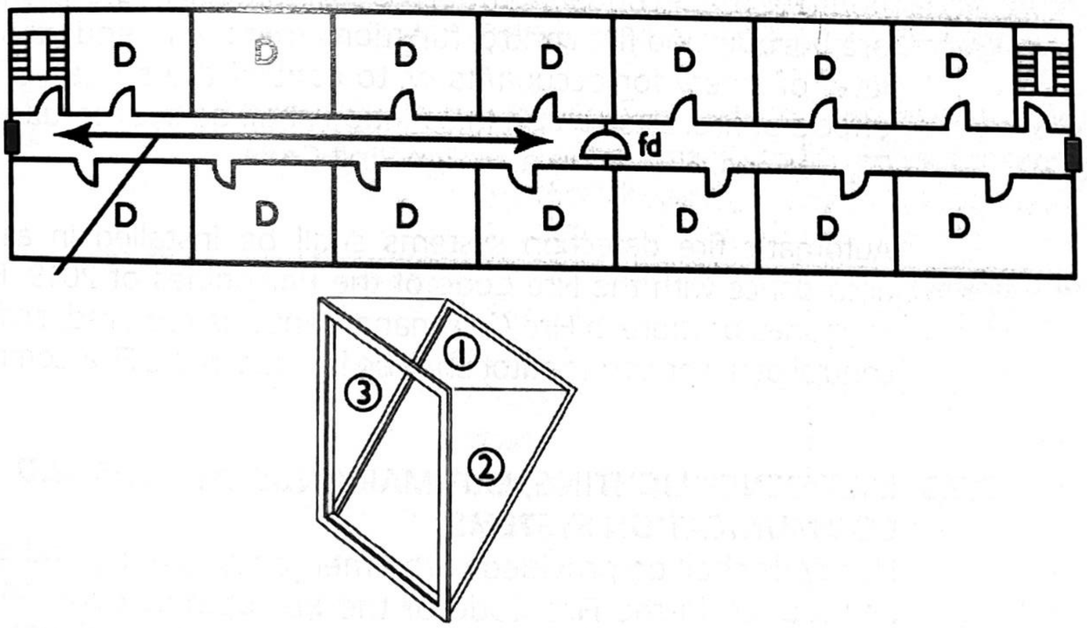
2.7.1 SMOKE CONTROL SYSTEM

Smoke control can be performed by passive means (smoke barriers and natural ventilation) and or active systems. Active systems consist of mechanical smoke extraction or smoke pressurization systems. The Fire Code of the Philippines requires a zoned smoke control system for all high-rise buildings. High-rise buildings also require that exit stairs be smoke-proof. Interior stairs to become smoke-proofed are pressurized. A zoned smoke control system using both pressurization (non-fire floor) and extraction (fire floor) can inadvertently push smoke in the stairwell and it is not recommended (Handbook of Smoke control). Zoned smoke control using extraction is the only one recommended for high-rise buildings. Smoke extraction can be done by natural means (venting) or mechanical means.

Smoke Control Smoke Venting. A smoke control system can be achieved using vents and smoke barriers to control the movement of smoke. The strategy is to vent out smoke and contain it in its room of origin.

Smoke venting in rooms. If fire starts in the patient rooms, each patient room must have an outside wall and operable window. Automatic fire detectors will alert the hospital staff of the presence of fire and its location. Staff can respond by going to the fire origin, evacuating the patient, opening the window to vent smoke, and doing manual fire-fighting. The room is separated from adjacent spaces by a resistive compartment and with fire-rated doors and an automatic door closer. Hospitals must also have a sprinkler system so as fire grows, the sprinklers can activate and control or extinguish the fire. In this way, fire and smoke can be confined and smoke vented from the room where the fire had originated.

Smoke Venting in Corridors. In case the fire starts in the corridor, a window at the end of the corridor or an automatic operable Vent (AOV) can be used to vent our smoke in the corridor. Cross ventilation is preferred than single-sided ventilation. The free area of the window or the AOV shall be at least 10% of the ventilated space or 1.5 square meters, whichever is greater.



Automatic Operable Vent (AOV)

Figure 2.5 Operable Window or AOV in the Exterior Wall of the Corridor

For mechanical exhaust, the extraction rate shall be a minimum of **50 cubic meters per minute** (1,764 cfm) or as recommended in NFPA 92, Standard for Smoke Control System. A zoned smoke control system using an extraction fan requires regular maintenance and testing. A complicated controls system will possibly require the use of a building automation system to operate which exhaust fan or damper will open or close. Regular system maintenance is needed to keep them ready to operate in case of emergency. This type of system shall be subjected to functional and performance testing prior to acceptance of the system.

The mechanical exhaust system, if activated automatically, shall be set to operate at a higher temperature than the activation temperature of the automatic sprinkler system. Air handling units are assumed to automatically shut down upon detection of smoke. NFPA 90A, Standard for the Installation of Air-conditioning and Ventilation System, requires the installation of smoke detectors that will automatically shut down air handling units with capacities greater than 944 liters per second (2,000 cubic feet per minute).

For Hospitals with atriums, an engineered smoke control system shall be provided.

2.7.2 FIRE ALARM AND DETECTION SYSTEM

The primary purpose of a fire alarm system is to notify the appropriate people and initiate the proper response from those people who are notified. The secondary purpose is to initiate fire safety functions, which are building and fire control functions that are intended to increase the level of safety for occupants or to control the spread of the harmful effects of fire. Design and Installation shall be in accordance with NFPA 72, National Fire Alarm and Signaling Code.

Automatic fire detection systems shall be installed in all hospitals in accordance with the Fire Code of the Philippines of 2019. For buildings, 10 stories or more, a Fire Command Center is required, and a Fire alarm control panel or annunciator shall be located in the Fire Command Center.

2.7.3 EMERGENCY LIGHTING, EXIT MARKINGS, ALARMS AND COMMUNICATION SYSTEMS

Hospitals shall be provided with emergency lighting and exit markings as required in the Fire Code of the Philippines. Location, dimension, illumination of emergency lighting, and exit markings shall be in accordance with NFPA 101, Life safety Code, and NFPA 99, Health Care Facilities Code.

2.7.4 FIRE SUPPRESSION SYSTEM

The objective of a fire suppression system is to control or extinguish the fire in its early stages. These suppression means can be manual (fire extinguishers, fire hoses) or automatic (sprinkler systems, gas extinguishing systems, etc.). The primary goal of these suppression means is to limit property damage and to control the fire before it becomes hazardous to people not close to the fire or to intervention teams. Due to the vulnerability of the patients, the system should be part of a strategy to keep the fire in the room of fire origin.

Automatic sprinkler systems that are well-designed and maintained are considered the most effective and reliable fire suppression system available. Statistical information shows that approximately 95% of fires are confined to the room of origin when a sprinkler system is installed. Sprinkler systems should be designed in accordance with National Fire Protection Association (NFPA) Standards. Sprinkler installation design is based on minimum spray densities over a maximum area of operation. The higher the sprinkler occupancy classification of the rooms, the higher the requirements will be for the spray densities and the area of operation. The water supply should be reliable. Installing a dedicated fire water tank and a fire pump that is UL listed or FM approved is recommended. The fire pump should have a reliable power source: an electric-driven pump should be connected to an emergency generator, or an engine-driven fire pump should be installed instead. Furthermore, the installation of valves in the system should monitor the closing of normally open valves should cause a trouble alarm in the system: statistics show that most sprinkler systems fail due to a closed valve.

In hospitals, discussions often arise on sprinkler protection in surgery rooms and rooms with expensive medical equipment. The following arguments are in favor of the use of sprinklers:

Sprinkler systems are highly reliable. Should unwanted activation be a concern, a pre-action system can further decrease the potential of unwanted activation of a sprinkler head.

Sprinklers only activate at a temperature of a minimum 68°C. One can expect that if the room is occupied when the fire ignites, the personnel has suppressed the fire before the sprinklers activate. The sprinkler system can be seen as a system that will control larger fires.

Most fires are normally controlled by two sprinklers, not all sprinklers in the room or compartment will be activated at once. Water damage will, therefore only occur near the fire.

Approved, supervised sprinkler system shall be provided throughout all hospitals and nursing homes, except for one (1) storey building with a bed capacity of not exceeding five (5). Replenishment of water supplies shall be strictly considered in the design. Quick-response sprinklers shall be required in smoke compartments containing patients' sleeping rooms.

Design and installation of the Automatic sprinkler system shall be in accordance with NFPA 13, Standard for the Installation of Automatic Sprinkler, NFPA 14 Standard for the Installation of Standpipe and Hose System, NFPA 20 Standard for the Installation of Stationary Pumps for Fire Protection, and NFPA 22, Standard for Water Tanks for Private Fire Protection.

a. Sprinkler systems shall be hydraulically calculated in accordance with NFPA13, Standard for the Installation of Sprinkler Systems.
b. Coordinate the sprinkler zoning with the smoke compartments and fire alarm zones.
c. Provide a flow switch, isolation valve, tamper switch, and pressure gage for each zone.
d. Specify non-ferrous piping for all areas within Magnetic Resonance Imaging (MRI) suites.
e. Determine and identify on drawings the location of fire pump, risers, all valves, fire department connections, drains, and points of connection with underground fire service main.

Standpipes can be used for manual fire-fighting by hospital staff, the fire brigade, or the responding fire department personnel. Standpipes can be combined with the automatic sprinkler system. Design and installation shall be in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems and NFPA 14, Standard for the Installation of Standpipes and Hose Systems.

Gaseous Extinguishing system can be used for critical areas. These systems are commonly used in server rooms or other similar areas where continuity of operation is the priority. It is advised to install such a system if a fire in the room can lead to a large business interruption or a high-value loss. The design of Gaseous extinguishing systems shall be in accordance with NFPA 12, Standard on Carbon dioxide Extinguishing Systems and or NFPA 2001, Standard for Clean Agent Fire Extinguishing Systems.

An automatic dry chemical or wet chemical system can be used for the protection of kitchen hoods and equipment. Fire Code of the Philippines requires that all commercial cooking operations shall be provided with automatic suppression systems like dry chemical or wet chemical extinguishing systems. The design of these systems shall be in accordance with NFPA 17, Standard for Dry Chemical Extinguishing System, and or NFPA 17A, Standard for Wet Chemical Extinguishing System.

2.7.5 PROTECTION FROM HAZARDS

The following areas shall be considered hazardous areas and shall be protected by fire barriers having a minimum 2-hour fire resistance rating in accordance with the requirement of the Fire Code of the Philippines:

Boiler and fuel-fired heater rooms
Laundries
Kitchens
Gift and Handicraft Shops
Employees Locker Rooms
Trash Collection Rooms
Soiled Linen Rooms
Paint shops
Storage rooms

2.8 TESTING AND COMMISSIONING OF FIRE PROTECTION AND LIFE SAFETY SYSTEMS

Commissioning. A systematic process that provides documented confirmation that building systems function according to the intended design criteria set forth in the project documents and satisfy the owner's operational needs, including compliance with applicable laws, regulations, codes, and standards. Testing and commissioning of the fire protection and life safety system shall be in accordance with NFPA 3, Recommended Practice for Commissioning of Fire Protection and Life Safety Systems.

Prior to the beneficial occupancy of the newly constructed, altered, or modified buildings, one (1) set of Fire Safety Compliance Commissioning Report (FSCCR) together with Certificate of Completion of Construction duly signed by the Contractor/Construction Manager and his/her Fire Safety Practitioner shall be submitted to the City or Municipal Fire Marshall having jurisdiction by the building owner. The FSCCR shall contain a certification that the plans and specifications prescribed in the FSCR for Building Permit were duly implemented. For modifications made, a detailed compilation of plans, specifications, and design analysis of the implemented changes shall be reflected in the "as-built" plans.

The contractor, construction manager, or person in charge of the construction and their fire safety practitioners shall certify that all fire protection and life safety features indicated in Fire Safety Compliance Report (FSCR) for Building Permit, including amendments thereto, which must be approved by concerned authorities, have been properly installed and implemented. They shall also certify that the building complies with the fire safety requirements of the fire Code of the Philippines (RA 9514) and its implementing rules and regulations.

2.9 REFERENCES

1. RA 9514, Fire Code of the Philippines 2019
2. NFPA 3, Recommended Practice for Commissioning of Fire Protection and Life Safety Systems.
3. NFPA 12, Standard on Carbon dioxide Extinguishing Systems
4. NFPA 13, Standard for the Installation of Automatic Sprinkler
5. NFPA 14 Standard for the Installation of Standpipe and Hose System
6. NFPA 17, Standard for Dry Chemical Extinguishing System
7. NFPA 17A, Standard for Wet Chemical Extinguishing System.
8. NFPA 20 Standard for the Installation of Stationary Pumps for Fire Protection
9. NFPA 22, Standard for Water Tanks for Private Fire Protection.
10. NFPA 72, National Fire Alarm and Signaling Code
11. NFPA 90A, Standard for the Installation of Air-conditioning and Ventilation System
12. NFPA 92, Standard for Smoke Control System
13. NFPA 99, Health Care Facilities Code.
14. NFPA 101, Life safety Code
15. NFPA 2001, Standard for Clean Agent Fire Extinguishing Systems
16. Handbook of Smoke Control Engineering

3.0 LIFTS AND CONVEYANCES

3.1 GENERAL CONSIDERATIONS

3.1.1 The purpose of this section is to provide guidelines and requirements for the design, construction, installation, and testing of passenger and material lifts and conveyances in a healthcare facility.

3.1.2 The term lifts and conveyances refers to elevators and escalators.

3.1.3 The latest edition of the publications listed constitutes the minimum requirements for elevator and escalator systems, including design, methods of construction, manner of installation, and testing.

(1) American Society of Mechanical Engineers (ASME) A17.1 / Canadian Standards Association (CSA) B44 - Safety Code for Elevators and Escalators

(2) American Society of Mechanical Engineers (ASME):

A17.2 – Guide for Inspection of Escalators, Elevators and Moving Walks
A17.3 – Safety Code for Existing Elevators and Escalators
A17.4 – Guide for Emergency Personnel
A17.5 – Elevator and Escalator Electrical Equipment
A17.6 – Standard for Elevator Suspension, Compensation, and Governor Systems
A18.1 – Safety Standard for Platform Lifts and Stairway Chairlifts

(3) National Fire Protection Association (NFPA):

13 – Standard for the Installation of Sprinkler Systems
70 – National Electrical Code
72 – National Fire Alarm and Signaling Code
101 - Life Safety Code
252 – Standard Methods of Fire Tests of Door Assemblies
QEI-1 – Standard for the Qualification of Elevator Inspectors

(4) American Society of Safety Professionals (ASSP) A10.4 – Safety Requirements for Personnel Hoists and Employee Elevators on Construction and Demolition Operations

(5) Philippine Mechanical Engineering Code

(6) Philippine National Building Code

(7) Fire Code of the Philippines

(8) National Structural Code of the Philippines

3.1.4 Elevators can be provided in all facilities having two (2) or more floors and designed to handle the anticipated traffic. In sizing the passenger and service elevators, the transport of equipment used by persons with special needs shall be taken into account.

3.1.5 For buildings five (5) storeys and more in height, new elevators shall conform to the firefighters' emergency operations requirements of **ASME 17.1. Safety Code for Elevators and Escalators.**

3.2 ESCALATORS, ELEVATORS AND DUMBWAITERS SIZING

3.2.1 ESCALATORS RATING AND CAPACITIES. Escalators are rated in two (2) ways, by nominal width and speed. Table 4.1 indicates the various typical speed and carrying capacity of escalators.

Table 3.1 - Escalator Capacity

Nominal Width, mm	Speed, fpm	Maximum Capacity, persons/hr	Nominal Capacity, persons/hr (75 per cent)
800 (1.25 persons/ step)	90	5,000	3,750
	120	6,700	5,025
1200 (2 persons/ step)	90	8,000	6,000
	120	10,700	8,025

3.2.2 ELEVATOR RATING, CAPACITY, LOCATIONS AND TRAFFIC STUDY CONSIDERATIONS

3.2.2.1 Locations

(1) Locate elevators to serve all floors that require service, including basement, sub-basement, interstitial spaces, and overhead mechanical spaces.

(2) Where one elevator would meet the service requirements for a healthcare building, provide two (2) elevators to ensure continuity of service where patient transportation is essential. However, if additional patient transport elevators are within 30.5 meters and serve the same landings, a second elevator may not be required.

(3) Elevators shall be grouped in banks of adjacent elevators or banks of elevators facing each other. Do not exceed three (3) service elevators in-line, three (3) passenger elevators in-line, and not more than six (6) cars in a group of three (3) facing three (3). The lobby width between two banks of passenger elevators shall not be less than 3.65 meters. Service elevator lobbies shall not be less than 4.25 meters.

(4) The maximum walking distance from patient elevators to the most distance check-in area or rest area with seating should not exceed 45.5m. Elevators for patient transport, hospital services, and staff, the maximum walking distance from elevators to the most distant patient room shall not exceed 60.5 meters. These factors should be weighed along with the advantages of locating elevators near the center of the building and the advantage of elevator clustering. Decentralized elevators should be planned to include at least two (2) elevators and maintain an acceptable average interval of approximately <50 seconds.

3.2.2.2 Estimating the number of elevators required. The criteria for acceptable elevator performance shall be based on the following Elevator Performance Tables.

Table 3.2 - Passenger Elevators Over the 5-Minutes Peak

Building Type	Average Interval Required	Minimum Handling Capacity
Hospital – Medical Center	Under 35 seconds	15% of the calculated building elevator population for the zones serviced (plus 20% migration for multiple elevator groups)
Outpatient Clinic	Under 40 seconds	15% of the calculated building elevator population for the zones serviced (plus 10% migration for multiple elevator groups)
Office Buildings	Under 45 seconds	12% of the calculated building population
Parking Garage	Under 45 seconds	110% of the calculated elevator population of the zones serviced.

Table 3.3 - Patient / Materials Handling Service Elevators Over the 5-Minutes Peak

Building Type	Average Interval Required	Minimum Handling Capacity
Hospital – Medical Center	Under 40 seconds	15% of the calculated building elevator population for the zones serviced (plus migration)
Outpatient Clinic	Under 45 seconds	15% of the calculated building elevator population for the zones serviced (plus migration)

Table 3.4 - Patient Service And Patient Equipment Only Service Elevators Over the 5-Minutes Peak

Building Type	Average Interval Required	Minimum Handling Capacity
Hospital – Medical Center	Under 40 seconds	115% of the calculated traffic
Outpatient Clinic	Under 45 seconds	110% of the calculated traffic

3.2.3 ELEVATOR TYPE, SIZE AND CAPACITY

3.2.3.1 Elevators are to be provided to address the two (2) vertical traffic in hospitals.

(1) Passenger Elevators for pedestrian traffic consist of hospital staff, doctors, technicians, volunteers, visitors, and ambulatory patients.

(2) Service Elevator for vehicular traffic consists of patients on stretchers, beds, wheelchairs, linen carts, food trucks, supply casts and portable equipment.

3.2.3.2 The size and capacity of the elevator shall consider the maximum size and weight of portable equipment, carts, beds, stretchers, and other loads to be transported.

3.2.3.3 In small hospitals, which require two (2) or three (3) elevators, the efficiency of the passenger elevator can be sacrificed to obtain flexibility of operation.

3.2.3.4 In any hospital requiring four (4) or more elevators, the passenger and service elevators' traffic separation is recommended.

3.2.3.5 **Elevator Capacity and Platform Design.** The following table indicates the elevator capacity and platform design.

Table 3.5 – Elevator Capacity and Platform Design

Elevator Type	Doors	Minimum Capacity, kg
Passenger Elevators	Single-speed center opening doors	1,818
Passenger/Service Elevators	Two (2) speed side opening or center opening doors	2,250
Service Elevators	Two (2) speed side opening or center opening doors	2,273
Bariatric and Trauma Elevators	Center opening doors or two (2) speed side opening doors	2,727
Freight Elevators	Vertical by-parting doors	Sized to handle intended service

3.2.4 DUMBWAITERS

3.2.4.1 Dumbwaiters' car lift platform should be sized to accommodate the largest cart selected for dietary, linen, or other material distribution in the facility.

3.3 OTHER DESIGN AND CONSTRUCTION CONSIDERATIONS

3.3.1 ELEVATOR ENCLOSURE

3.3.1.1 The car enclosure is intended to protect passengers from becoming entangled with the hoistway equipment when the car is moving, falling out of the car, and being injured by falling objects. It must be constructed in such a manner that it cannot be dismantled from within the car.

3.3.1.2 The car top should carry the weight of elevator personnel, emergency personnel, and others who might be on top of the car evacuating people from a stalled elevator.

3.3.1.3 The glass installed should meet the requirements for laminated glass in ANSI Z97.1.

3.3.2 ELEVATOR DOORS AND ENTRANCES

3.3.2.1 Elevator door assemblies and entrances shall have a minimum of one (1) hour fire protection rating.

3.3.2.2 Provide power door operation for all elevators. Non-healthcare facilities may use industry-standard door sizes and entrance frames.

(1) Passenger/Service door operator shall be capable of opening doors at the rate of 0.75 m/s, with actual speed being adjusted to meet the requirements of the specific installation. Freight door operator shall open at 0.3m/s.

(2) Closing speed shall be 0.3m/s. All power-operated doors shall be equipped with an automatic reopening device for passenger protection. In healthcare facilities, do not activate door nudging. Use an audio voice announcement, "please stand clear of the doors," and activate the nudging buzzer.

3.3.2.3 Entrances for Passenger, Service and Freight Elevators

(1) Doors shall be center openings for passenger elevators and center or side openings for service elevators in healthcare facilities. Hoistway doors shall be reinforced two-panel construction with stainless steel on the outside surface, wrapped around leading edges. Use only center-opening doors for facilities that require three (3) or more attendants and possibly equipment to accompany patient transport.

(2) Passenger elevator entrance width 1200 mm standard.

(3) Service elevator entrance width: minimum 1200 mm, larger if required by facilities function.

(4) Door minimum opening height: 2100mm.

(5) Curved hoistway entrance side jambs shall be 3.5" radius for passenger and service elevators in healthcare facilities.

3.3.3 OPERATING FIXTURES

3.3.3.1 All operating fixtures and devices shall be enclosed electric type to prevent accidental contact and should be self-centered switches. These devices are not limited to push-button, switches, levers, and other manual devices used to actuate a control.

3.3.3.2 The operating device for one-piece safe lift operation shall be a continuous pressure type with the speed restricted at 0.75 m/s or 150 FPM.

3.3.4 CONTROL SYSTEMS

3.3.4.1 Provide a microprocessor system with absolute position/speed feedback to control dispatching, signal functions, door operation, and hoist/pump motor control.

3.3.4.2 Microprocessor dispatching system shall evaluate building traffic demand, including number of elevators in service, hall calls, car calls, elevator position, direction of travel, load in elevator, and door status, and select an elevator to answer hall calls for the least possible passenger wait times.

3.3.4.3 Car lights and fans in the elevator may shut off when the elevator is idle. Provide power thru a failsafe relay that is energized to turn off lights and fans. Arrange circuits so that power to the lights and outlets on top and bottom of the elevator shall not be interrupted.

3.3.5 ELEVATOR MACHINE ROOMS

3.3.5.1 Elevator machine rooms should be maintained between 13C and 32C with relative humidity not exceeding 90%.

3.3.5.2 Access doors shall be self-closing and self-locking to ensure access only by authorized personnel. The key must be kept in the building and available only to authorized personnel.

3.3.5.3 The minimum headroom clearance shall be 2,400mm.

3.3.5.4 Elevator machine rooms, spaces, control spaces, and control rooms; no electronic and radio transmission equipment is located in elevator machinery spaces. This requirement also prevents unauthorized personnel from entering the spaces.

3.3.6 ELEVATOR HOISTWAYS

3.3.6.1 Elevator hoistway enclosure walls shall be concrete with a two (2) hours fire rating.

3.3.6.2 The interior face of the hoistway walls shall have a smooth, flush, and non-dust-producing surface.

3.3.6.3 Hoistway entrance operating mechanisms and locking devices can be supported by the wall if the wall is load-bearing (masonry, brick, concrete block, etc.),

3.3.7 ELEVATOR PITS

3.3.7.1 All pits for elevators that have Firefighters' Emergency Operation be provided with a drain or sump pump. The pit drainage shall be designed to remove a minimum capacity of 50 GPM per elevator car.

3.3.7.2 When the pit floor is more than 900 mm below the sill of the pit access door, a fixed retractable or non-retractable pit ladder must be installed.

3.3.7.3 Illumination and duplex receptacles should be provided.

3.3.7.4 Provide two (2) stop switches at 1200 mm above the bottom landing at the top of the pit ladder and 1200 mm above the pit floor adjacent to the pit ladder for maintenance and safety.

3.3.8 ELECTRICAL REQUIREMENTS

3.3.8.1 Each elevator shall be provided with a separate disconnect and surge suppressor in the respective machine room located adjacent to the entry. The supply shall terminate at the respective elevator controller. The elevator power supply shall be a dedicated main feeder utilizing the shortest practical run and continuous ground conductor.

3.3.8.2 Emergency power supply shall have the capacity to operate a minimum of one elevator per group.

(1) If an emergency generator is not available, traction elevators shall be provided with an emergency power system that will run the elevator to the nearest floor and open the doors.

(2) If an emergency generator is not available, hydraulic elevators shall be provided with an emergency lowering system to lower the elevator to the bottom floor and open the doors.

3.3.8.3 Fire Alarm Initiating Devices shall be installed in accordance with the requirements of NFPA 72: National Fire Alarm Code.

3.3.8.4 Provide a circuit breaker panel or disconnect switches lockable in the off position in each machine room for emergency power circuit for car lights, fan, and alarm, circuit for the machine room GFCI receptacles, circuit for the hoistway lights, circuit for hoistway receptacles and circuit for the scavenger pump in the pit for the hydraulic elevator.

(1) Hoistway lights if provided, shall be stacked vertically in the rear of the hoistway near the corner for a single elevator or on the back wall between the divider beams of a duplex or triplex installation. The extreme top and bottom fixtures shall be mounted to illuminate the pit area when the car is at the bottom landing and the car top when the car is at the top landing. Provide three-way light switches at the top of the pit ladder and 1520mm above the top of the terminal landing at the inside front wall near the hall button box.

4.0 MEDICAL GAS AND VACUUM SYSTEMS

4.1 GENERAL CONSIDERATIONS

4.1.1 The purpose of this section is to provide guidelines for the design, installation, testing and verification of medical gas and vacuum systems.

4.1.2 The term medical gas or vacuum applies to all pipe systems for oxygen, nitrous oxide, medical air, carbon dioxide, helium, medical surgical vacuum, waste anesthetic gas disposal, nitrogen, instrument air, and mixtures thereof.

4.1.3 The latest editions of the publications listed constitute the minimum requirements for medical gas and vacuum systems, including design, construction methods, installation, and testing.

(1) National Fire Protection Association (NFPA) 55 – Compressed Gases and Cryogenic Fluids Code
(2) National Fire Protection Association (NFPA) 99 – Health Care Facilities Code
(3) Philippine Mechanical Engineering Code
(4) American National Standard Institute/American Society of Safety Professionals (ANSI/ASSP) 6010 – Professional Qualification Standard for Medical Gas and Vacuum Systems Installers
(5) American Society of Plumbing Engineers (ASPE)

4.2 MEDICAL GAS AND VACUUM PIPING SYSTEMS

4.2.1 Piping Material

4.2.1.1 The piping material for medical gases shall be hard-drawn **Type K or L copper tube** and shall comply with the requirements of ASTM B819, Standard Specification for Seamless Copper Tube for Medical Gas Systems, and the requirements of NFPA 99 - Health Care Facilities Code.

4.2.2 System Pressure

4.2.2.1 Medical gas and vacuum systems shall be designed to deliver the following pressures listed in Table 5.1 at the points of use for the longest pipe run:

Table 4.1 - System Pressures

Medical Gas	Outlet Pressure
Oxygen*	345 kPa (50psig).
Nitrous Oxide	345kPa (50psig)
Nitrogen	1448 kPa (210 psig)
Medical Air	345kPa (50 psig)
Medical Vacuum	51 kPa (15 in. Hg)
Carbon Dioxide	345kPa (50 psig)
WAGD	20kPa (6 in. Hg)

In designing oxygen systems with adult ventilators, size the piping system based on the instantaneous demand based on 3.3 liters/sec for each ventilator from the outlet back to the source.

4.2.3 Piping Systems and Sizing Considerations

4.2.3.1 All systems shall comply with **NFPA 99 requirements**. Bulk gas systems shall be designed in accordance with **NFPA 55**.

4.2.3.2 In sizing the piping system, the following factors are to be considered:

a. total connected flow rate,
b. diversity factor,
c. allowable friction loss, and
d. equivalent length of piping.

4.2.3.3 The following tables on flow rates and diversity factors can be used in the sizing of the piping system.

Table 4.2 – Flow Rate and Diversity Factor for Low-Pressure Medical Air Outlets and Proportioned Air

Air outlet/equipment	Design flow in scfm* (free air)				
	Per unit	Per room	Per bed	Per outlet	Simultaneous-use factor, %
Anesthetizing Locations:					
Special surgery and cardiovascular		0.5			100
Major surgery ad orthopedic		0.5			100
Minor surgery		0.5			75
Emergency surgery		0.5			25
Radiology		0.5			10
Cardiac catheterization		0.5			10
Ventilators	5				100
Delivery rooms		0.5	0.5		100
Cystoscope					100
Acute Care Locations:					
Recovery room/surgical (postanesthesia)			2		25
ICU/CCU			2		50
Emergency rooms			2		10
Neonatal ICU			1.5		75
Dialysis units			0.5		10
Recovery rooms/OB		2			25
Ventilators	6				100

4.2.3.4 On piping system friction loss, generally, the pressure piping system should be designed so as **not to exceed 10 percent of system working pressure**. Design vacuum piping systems **not to exceed 10kPa (3 in. of Hg) loss** for the longest run of pipe.

4.2.3.5 On Gas pipe sizing, the minimum size of medical gas mains and branches is **15 mmø.**

4.2.3.6 On Medical Vacuum system sizing, the minimum size of vacuum piping mains and branches shall be **20 mmø** and **15 mmø** for drops to individual station outlets and inlets.

4.2.3.7 Provide main line supply line with a shut-off valve accessible by authorized personnel only.

4.2.3.8 Each branch or riser supplied from the main line shall have an in-line shut-off valve adjacent to the main. Each branch supplied from a riser shall have an in-line shut-off valve, adjacent to the riser. Conceal in-line shut-off valves and make provisions to lock it open.

4.2.3.9 Include a zone valve in a cabinet with other medical gas zone valves for all anesthetizing locations and branches serving station outlets and inlets in conformance with NFPA 99.

4.2.3.10 Except for nitrogen systems, medical gas station outlets and vacuum station inlets in new buildings shall be quick coupler type. Where building alterations or additions occur, station outlets and inlets shall be compatible with those of the existing building, without the use of secondary adapters.

4.2.3.11 Provide a protective pipe enclosure for exterior oxygen line. Burial depth shall be minimum of 0.6 m below grade. Provide warning tape that is acid and alkali-resistant with a metallic core encased in a protective jacket, detectable by metal detector.

4.2.3.12 Design oxygen and medical air systems to accommodate the ventilators with the demand of **200 L/min**.

Oxygen System: Minimum design flow rate for any pipe section is **200 L/m**in.

Vacuum System: Minimum design flow rate for any pipe section is **113 L/min.**

Medical Air System: Minimum design flow rate for any pipe section is **200 L/min.**

4.2.3.13 The following tables are the recommended station outlets of the medical gas systems on a particular area of a healthcare facility.

Table 4.6 – AIA Guidelines for Vacuum and Air Systems for Hospital Facilities Station Outlets for Oxygen, Vacuum (Suction), and Medical Air Systems in Hospitals

Location	Oxygen	Vacuum	Medical Air
Patient rooms (medical and surgical)	1/bed	1/bed	-
Examination/treatment (medical, surgical, and postpartum care)	1/room	1/room	-
Isolation—infectious and protective (medical and surgical)	1/bed	1/bed	-
Security room (medical, surgical, and postpartum)	1/bed	1/bed	-
Critical care (general)	3/bed	3/bed	1/bed
Isolation (critical)	3/bed	3/bed	1/bed
Coronary critical care	3/bed	2/bed	1/bed
Pediatric critical care	3/bed	3/bed	1/bed
Newborn intensive care	3/bassinet	3/bassinet	3/bassinet
Newborn nursery (full-term)	1/4 bassinets	1/4 bassinets	1/4 bassinets
Pediatric and adolescent	1/bed	1/bed	1/bed
Pediatric nursery	1/bassinet	1/bassinet	1/bassinet
Psychiatric patient rooms	-	-	-
Seclusion treatment room	-	-	-
General operating room	2/room	3/room	-
Cardio, ortho, neurological	2/room	3/room	-
Orthopedic surgery	2/room	3/room	-
Surgical cysto and endo	1/room	3/room	-
Post anesthesia care unit	1/bed	3/bed	1/bed
Anesthesia workroom	1/work station		1/work station
Phase II recovery‡	1/bed	3/bed	-
Postpartum bedroom	1/bed	1/bed	-
Cesarean/delivery room	2/room	3/room	1/room
Infant resuscitation station§	1/bassinet	1/bassinet	1/bassinet
Labor room	1/room	1/room	1/room
OB recovery room	1/bed	3/bed	1/room
Labor/delivery/recovery (LDR)¶	2/bed	2/bed	-
Labor/delivery/recovery/postpartum (LDRP)5	2/bed	2/bed	-
Initial emergency management	1/bed	1/bed	-
Triage area (definitive emergency care)	1/station	1/station	
Definitive emergency care exam/treatment rooms	1/bed	1/bed	1/bed
Definitive emergency care holding area	1/bed	1/bed	-

Trauma/cardiac room(s)	2/bed	3/bed	1/bed
Orthopedic and cast room	1/room	1/room	-
Cardiac catheterization lab	2/bed	2/bed	2/bed
Autopsy room	-	1/work station	1/work station
**For any area or room not described above, the facility clinical staff shall determine outlet requirements after consultation with the authority having jurisdiction.* *Four bassinets may share one outlet that is accessible to each bassinet.* *If Phase II recovery area is a separate area from the PACU, only one vacuum per bed or station shall be required. §When infant resuscitation takes place in a room such as cesarean section/delivery or LDRP, then the infant resuscitation services must be provided in that room in addition to the minimum service required for the mother.* *Two outlets for mother and two for one bassinet.*			

4.3 MEDICAL GASES COMPONENTS AND INSTALLATION CONSIDERATIONS

4.3.1 Central Supply System Components. A Central supply system is consisting of the following:

(1) Cylinder manifolds for gas cylinders
(2) Manifolds for cryogenic liquid containers
(3) Cryogenic fluid central supply systems
(4) Medical air compressor systems
(5) Medical-surgical vacuum producers
(6) Waste Anesthetic Gas Disposal (WAGD) producers
(7) Instrument air compressor systems
(8) Proportioning system for medical air USP

4.3.2 Location. Locations for central supply systems and the storage positive-pressure gases shall consider the following:

(1) The location is secured and will allow access and movement of cylinders and equipment.
(2) If outdoors, an enclosure made of noncombustible materials shall be provided.
(3) A minimum of two (2) entry/exits is provided if the location is outdoors and greater than 18.6 m^2.
(4) If indoors, they shall have interior finishes of non-combustible or limited-combustible materials. Room shall be separated from the rest of the building by walls and floors having a 1-hour fire resistance rating with doors and other opening protectives having ¾-hour fire protection rating.

(5) Fuel-fired equipment shall not be located in the room.

(6) Any of the following central supply systems shall be permitted to be located together in the same outdoor enclosure:
   (a) Manifolds for gas cylinders
   (b) Manifolds for cryogenic liquid containers
   (c) Bulk cryogenic liquid systems
   (d) Individual components on the oxygen side of concentrator sources

(7) Any of the following systems shall be permitted to be located together in the same indoor enclosure:
   (a) Manifolds for gas cylinders
   (b) Manifolds for cryogenic liquid containers
   (c) In-building emergency reserves
   (d) Instrument air standby headers
   (e) Individual components on the oxygen side of concentrator sources

4.3.3 System Setup Considerations

4.3.3.1 A shut-off valve shall be provided for each medical gas and vacuum system at the immediate outlet (or inlet for vacuum system) of the source of supply, so that the entire supply source, including all accessory equipment, can be isolated from the entire pipeline system.

4.3.3.2 Medical air compressors and vacuum pumps shall be multiplexed with single receivers. Size compressors and pumps such that 100% of the peak design load is carried with the largest single unit out of service. Provide three-way valve bypass at receiver.

4.3.3.3 Medical air compressors and medical vacuum pumps shall serve the medical air and medical vacuum systems only.

4.3.3.4 Vacuum systems shall be protected with appropriate filtration (0.3micron hydrophobic filter) on the suction side of the pumps to minimize potential for contamination of the vacuum pumps.

4.3.3.5 Liquid oxygen containers and high-pressure gaseous oxygen shall either comply with appropriate requirements of the ASME Boiler and Pressure Vessel Code or be designed, constructed, tested and maintained in accordance with the US Department of Transportation (DOT) Specifications and Regulations.

4.3.3.6 Air compressors shall be a type that provides Medical Compressed Air as defined by NFPA 99.

5.0 WATER AND WASTEWATER MECHANICAL EQUIPMENT

5.1 GENERAL CONSIDERATIONS

Simplicity and reliability are keys in designing healthcare facilities for water and wastewater systems. Moreover, planning for operational efficiencies will keep these systems functioning optimally over the life of a facility. Knowing the demanding requirements of healthcare water and wastewater systems and the technical challenges specific to each hospital, as well as relevant codes and standards will aid facility personnel in maintaining these unique systems and fixtures. There are a number of plumbing systems that are unique to hospitals. This equipment will have distinctive requirements and maintenance considerations that must be understood for the hospital's infrastructure to run efficiently.

Because of the sensitivity of the healthcare environment and the importance of water to a hospital's patient care mission, there are many unique requirements that facilities professionals must consider when designing a healthcare plumbing system. They include:

Accessibility. Keeping plumbing equipment easily accessible is critical to maintaining it over time. Keeping valves in accessible spaces will minimize disruption to patients and hospital staff and will help to ensure that regular maintenance is performed as required.
Maintainability. Maintenance, as well as capital investments, must be considered prior to the design of the plumbing systems.
Redundancy. During one hospital's design, there is equipment that needs to be considered for redundancy so that the hospital operation will not be interrupted.
Serviceability. Mechanical equipment should have access to maintenance and servicing.

5.2 DESIGN CRITERIA

- Codes and Standards
    1. DAO 2016 28 – Water Quality Guidelines and General Effluent Standards 2016
    2. NFPA 99 – Standard for Health Care Facilities
    3. Uniform Plumbing Code - International Association of Plumbing and Mechanical Officials (IAPMO)
    4. National Plumbing Code of the Philippines
    5. ASHRAE Standard 188 – Legionellosis: Risk Management for Building Water Systems
    6. Bureau Of Product Standards (BPS)
    7. Philippine National Standards for Drinking Water
    8. Underwriters Laboratory (UL)
    9. DOH National / Laboratory (NRL)
    10. DOH Health Care Waste Management Manual
    11. National Water Resources Board (NWRB)
    12. National Building Code
    13. Philippine Mechanical Code

5.3 Water Supply and Distribution

5.3.1 Water Demand. Water demand will be computed according to the number of occupants.

5.4 Hot and Cold Water Requirement. Except where not deemed necessary for safety by the Authority Having Jurisdiction, each plumbing fixture shall be provided with an adequate supply of potable running water, piped thereto in an approved manner, so arranged as to flush and keep it in a clean and sanitary condition without danger of backflow or cross-connection. Water closets and urinals shall be flushed by means of an approved flush tank or flushometer valve. In occupancies where plumbing fixtures are installed for private use, hot water shall be required for bathing, washing, laundry, cooking purposes, dishwashing, or maintenance. In occupancies where plumbing fixtures are installed for public use, hot water shall be required for bathing and washing purposes. This requirement shall not supersede the requirements for individual temperature control limitations for public lavatories, bathtubs, whirlpool bathtubs, bidets, and shower control valves.

5.5 Identification of non-potable water systems. Where non-potable water systems are required and installed, each non-potable system shall be clearly identified. Its color and information for each system shall be identified with a colored pipe or band and coded with paints, wraps, and materials compatible with the piping non-potable water systems shall have a yellow background with black uppercase lettering, with the words: "CAUTION: NONPOTABLE WATER, DO NOT DRINK." Each non-potable system shall be identified to designate the liquid being conveyed, and the direction of normal flow shall be clearly shown.

5.6 Pipe Materials and Fittings

Materials for Building Supply and Water Distribution Pipe and Fittings

Material	Reference Standards Pipe	Reference Standards Fittings
CPVC	ASTM D2846, ASTM F441, ASTM F442	ASTM D2846, ASTM F1970, ASTM F437, ASTM F438, ASTM F439
PE	ASTM D2239, ASTM D2737, ASTM D3035, AWWA C901, CSA B137.1	ASTM D2609, ASTM D2683, ASTM D3261, ASTM F1055, CSA B137.1
PE-AL-PE	ASTM F1282, CSA B137.9	ASTM F 1282, ASTM F1974, CSA B137.9

PEX	ASTM F876 , ASTM F877, CSA B137.5	ASTM F877, ASTM F1807, ASTM F1960, ASTM F1961, ASTM F2080, ASTM F2159, CSA B137.5
PEX-AL-HDPE	ASTM F1986	ASTM F1986
PEX-AL-PEX	ASTM F1281, CSA B137.10, ASTM F2262	ASTM F1281, ASTM F1974, ASTM F2434, CSA B137.10
PPR	ASTM F2389, CSA B137.11	ASTM F2389, CSA B137.11
PVC	ASTM D1785, ASTM D2241, AWWA C900	ASTM D2464, ASTM D2466, ASTM D2467, ASTM F1970

5.7 Disinfection of Potable Water Systems. Potable water systems shall be disinfected prior to use whenever required by the Authority Having Jurisdiction. The method to be followed shall be that prescribed by the Health Authority or, in case no method is prescribed by it, the following:

- The pipe system shall be flushed with clean, potable water until only potable water appears at the points of outlet.
- The system or parts thereof shall be filled with a water-chlorine solution containing not less than 30mm/L (30 parts per million) of chlorine, and the system or part thereof shall be valved-off and allowed to stand for 1 hour.
- Following the allowed standing time, the system shall be flushed with clean, potable water until the chlorine residual in the water coming from the system does not exceed the chlorine residual in the flushing water.
- The procedure shall be repeated if it is shown by a bacteriological examination made by an approved agency that contamination persists in the system.

5.8 Sizing of potable water piping.

- The size of each water meter and each potable water supply pipe from the meter or other source of supply to the fixture supply branches, risers, fixtures, connections, outlets, or other uses shall be based on the peak demand and shall be determined according to the methods and procedures outlined in this section, engineering methods, or appendices A and L. Water piping systems shall be designed to ensure that the maximum velocities allowed by the code and the applicable standard are not exceeded.
- Where a water filter, water softener, backflow prevention device, or similar device is installed in any water supply line, the pressure loss through such devices shall be included in the pressure loss calculations of the system, and the water supply pipe and meter shall be adequately sized to provide for any such pressure loss. No water filter, water softener, backflow prevention device, or similar device shall be installed in any potable water supply piping when such device produces an excessive pressure drop in any such water supply piping. In the absence of specific pressure drop information, the diameter of the inlet or outlet of any such device or

its connecting piping shall be not less than the diameter of such water distribution piping to the fixtures the device serves. Such devices shall be of a type approved by the Authority Having Jurisdiction and shall be tested for flow rating and pressure loss by an approved laboratory or recognized testing agency to standards consistent with the intent of this chapter.

- The quantity of water required to be supplied to every plumbing fixture shall be represented by water supply fixture unit values.
- Except where the type of pipe used and the water characteristics are such that no decrease in capacity due to length of service (age of system) may be expected, all friction-loss data shall be obtained. Friction or pressure losses in the water meter, valve, and fittings shall be obtained from the same sources. Pressure losses through water-treating equipment, backflow prevention devices, or other flow-restricting devices shall be computed as required.
- On any proposed water piping installation sizing, the following conditions shall be determined: (1) Determine static pressure for highest outlet (elevation difference to highest outlet). (2) Determine friction head loss (pump to farthest fixture x 1.5 [equals equivalent length]). (3) Required outlet pressure [fixture with most pressure requirements (i.e. flush valves etc.)]. (4) Total number of water supply fixture units, Separate Cold and Hot Water Supply Fixture Unit Values.

5.9 Sizing for velocity. Maximum velocities in pipe, tubing, and fitting systems shall not exceed 2.4m/s (8 fps) in cold water and 1.5m/s (5 fps) in hot water.

5.10 Wastewater Treatment Facility

- Influent Wastewater Characteristics for Weak, Medium, and Strong Concentration

Contaminants	Unit	Weak	Medium	Strong
Solids, Total (TS)	mg/L	350	720	1200
Dissolved, Total (TDS)	mg/L	250	500	850
Fixed		145	300	525
Volatile		105	200	325
Suspended Solids (SS)	mg/L	100	220	350
Fixed		20	55	75
Volatile		80	165	275
Settleable Solids	mg/L	5	10	20
Biochemical Oxygen Demand, mg/L 5-day, 20 deg C (BOD_5, 20 deg C)	mg/L	110	220	400
Chemical Oxygen Demand (COD)	mg/L	250	500	1000
Total organic carbon (TOC)	mg/L	80	160	290
Nitrogen (total as N)	mg/L	20	40	85
Organic		8	15	35
Free Ammonia		12	25	50

Phosphorous (total as P)	mg/L	4	8	15
Organic		1	3	5
Inorganic		3	5	10
Chlorides	mg/L	30	50	100
Sulfate	mg/L	20	30	50
Alkalinity (as $CaCO_3$	mg/L	50	100	200
Grease	mg/L	50	100	150
Total Coliform	No/100mL	10^6 - 10^7	10^7 - 10^8	10^7 - 10^9
Volatile Organic Compounds (VOCs)	μg/L	<100	100-400	>400

- Effluent Discharge Requirements
  Guaranteed Effluent Result based on DAO 2016 - 08

BOD : 7 mg/L
Chloride : 350 mg/L
Color : 75 TCU
Dissolved Oxygen : 5 mg/L
Fecal Coliform : 200 MPN/100ml
Nitrate : 7 mg/L
TSS : 80 mg/L
O&G : less than 5 mg/L
pH : 6.5-9.0
Phosphate : 0.5 mg/L

5.10.1 Categories of Wastewater

Blackwater (sewage) is heavily polluted wastewater containing high concentrations of fecal matter and urine, food residues, and toxic chemicals.

Greywater (sullage) is low polluted wastewater with residues from: – washing, bathing, laboratory processes, laundry, or technical processes such as cooling water or the rinsing of X-ray films.

5.10.2 Sources of Healthcare Wastewater

Administration and wards
Kitchen
Laundry
Operating rooms and ICU
Laboratories
Radiology
Haemodialysis
Dental departments
Toilets
Offices and support departments

5.10.3 Wastewater contaminants
Anesthetics
disinfectants (formaldehyde, glutaraldehyde)
chemicals from laboratory activities
photochemical solutions (hydroquinone)
X-ray contrast media containing absorbable organohalogen compounds (AOX)
Mercury from dental amalgams or lab chemicals
Excessive nutrients and nitrates
Pharmaceuticals, including antibiotics
Radioactive wastes – Infectious agents, including bacteria, viruses and parasites

5.11 Type and Quality of Water

5.11.1 Filtered Water. The most common type of water for healthcare facilities. It is through the process of using carbon filters to remove the chlorine and a micron filter to remove suspended particles.

5.11.2 Soft Water. It is a type of water in calcium, magnesium, and certain other metals have been removed from hard water.

5.11.3 Pure Water. It's a purification process that separates the purified water from the rest of the pack. It goes through a process similar to what filtered water goes through but with a few added steps like reverse osmosis, distillation, and deionization. The end result is much purer than filtered water.

5.11.4 Distilled Water. It is a process of boiling H_2O out of its contaminants. Contaminants include inorganic minerals or metals. Those impurities have a much higher boiling point than the water's boiling point of 212 deg F. The steam that results from the boiling point is captured and cooled, and the water that results from the steam is classified as distilled water.

5.11.5 Recommended Quality and Type of Water

Area	Type of Water
Dialysis Center	Purified
Laboratories	Purified
Sterile Rooms	Purified and Soft
Toilets	Filtered

5.12 Mechanical Components for Water Distribution

5.12.1 Storage Tank. Storage tanks will be sized according to the population and the average water consumption per day of each occupant as described in NPCP and UPC.

5.12.2 Pumps. Pumps will be sized according to the computed flow rate and the total dynamic head. An appropriate type of pump should be used so that it will prevent the pump from cavitation.

6.0 EMERGENCY DIESEL GENERATOR SYSTEM

6.1 GENERAL REQUIREMENTS

Emergency diesel generator systems shall be designed and installed in accordance with NFPA 110, Standard for Emergency Power Supply Systems.

Reliability and Maintainability. Diesel generator systems shall be designed to maximize operating reliability and ease of maintenance. Space must be provided around equipment and components for easy access. Controls should be provided in multiple unit installations to prevent maintenance activity taking place on one unit from interfering with operating units.

6.2 VENTILATION

Diesel generator sets require a significant volume of ventilation and combustion air. Locate the room housing the diesel generator set on the exterior side of buildings or detached structure for good ventilation. At least two sides of the room shall be utilized for inlet and outlet of air. The room shall be provided with a cross-ventilation system to optimize the cooling of the engine and generator. Inlet louvers shall not be blocked by panels or any obstruction that will deflect ventilation air from the engine generator set. Ventilation air volume for the diesel generator system shall consider heat radiated from the engine ,the generator, and other heat-producing equipment in the room. Refer to the manufacturer's data for the heat radiated by the engine and generator and use this for ventilation calculation.

Inlet openings shall be able to accommodate the required air for ventilation and combustion air requirements. Refer to the manufacturer's data for this item. Radiator air discharge shall be ducted outdoors. Discharge air from the radiators shall be directed outside.

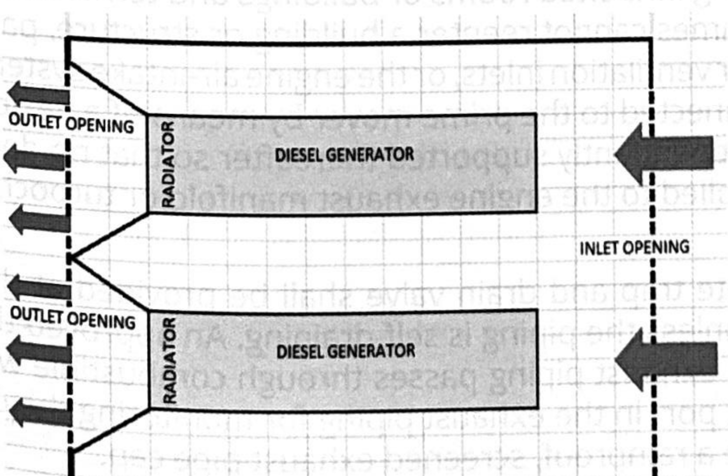


Figure 6.1 - Cross Ventilation For The Genset Room

6.3 FUEL TANKS

Fuel tanks and systems shall be installed and maintained in accordance with NFPA 30, Flammable and Combustible Liquids Code; NFPA 37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines.

Fuel Storage and Day Tank Volumes. Use above-ground storage tanks within diked areas or as a means of containment in case of a fuel leak. Containment or enclosure volume for the fuel tank shall be enough to contain the volume of fuel in the biggest storage tank. Provide a minimum of 3-day storage capacity for the fuel storage. For areas that are remote and delivery of fuel may take longer, consider increasing the fuel storage tank capacity. Storage tank volume shall be based on the rate of fuel consumption of all engines at 100 percent load. The use of underground storage tanks may be considered, provided that leak detection and double containment provisions are provided.

Day tank volumes shall be determined based on the following: Provide automatically filled day tanks. Day tank capacity shall be based on 8 hours of full-load operations. Provide a day tank and transfer pump unit for each engine, as recommended by the engine manufacturer.

6.4 EXHAUST SYSTEM

The exhaust system equipment and installation, including piping, muffler, and related accessories, shall be in accordance with NFPA 37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines. Exhaust system installation shall be gastight to prevent exhaust gas fumes from entering inhabited rooms or buildings and terminate in such a manner that toxic fumes cannot reenter a building or structure, particularly through windows, air ventilation inlets, or the engine air-intake system. Exhaust piping shall be connected to the prime mover by means of a flexible connector and shall be independently supported thereafter so that no damaging weight or stress is applied to the engine exhaust manifold or turbocharger.

A condensate trap and drain valve shall be provided at the low point(s) of the piping unless the piping is self-draining. An approved thimble(s) shall be used where exhaust piping passes through combustible walls or partitions. Provide test port in the exhaust piping for monitoring the quality of exhaust gas. Provide a rainproof, screened exhaust pipe cap.

Exhaust Muffler. Shall be a Critical grade type.

Pressure drop in the complete exhaust system shall be small enough for satisfactory operation of the engine-generator set while it is delivering 110 percent of its specified rating.

Exhaust pipe size, from the engine to the muffler, shall be as recommended by the engine manufacturer. The pipe size from the muffler to air discharge shall be two-pipe sizes larger than the engine exhaust pipe. Exhaust pipe shall be provided with insulation.

6.5 REFERENCES

1. NFPA 30, Flammable and Combustible Liquids Code

2. NFPA 37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines

3. NFPA 110, Standard for Emergency Power Supply Systems

MASTER PLUMBERS